THE JOURNAL OF POMOLOGY AND HORTICULTURAL SCIENCE

VOL. VI

PUBLISHED BY
HEADLEY BROTHERS
18, Devonshire Street, Bishopsgate, E.C.2
London, England

PRINTED AND MADE IN GREAT BRITAIN BY HEADLEY BROTHERS, ASHFORD, KENT.

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JOURNAL OF POMOLOGY. VOL. VI.

THE INFLUENCE OF DIFFERENT ROOT STOCKS UPON THE VIGOUR AND PRODUCTIVITY OF THE VARIETY BUDDED OR GRAFTED THEREON.

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Six years have elapsed since a preliminary paper dealing with this subject was published in the Journal of Pomology (1). Since then a considerable body of data has accumulated which has an immediate application both for the worker in Horticultural Science and for the practical Fruit grower, and so a return to the subject is thought to be justified.

Summary of Conclusions Published to Date.

In 1920 it was recalled that a classification of the root stocks in commerce by means of botanical characters was possible (2 and 3), and that vegetative methods of raising could be applied to a far wider range of stocks than heretofore (4). In addition, the advantages of using stocks so raised, in preference to chance seedlings, were emphasised, in view of the greater control of the tree that seemed likely to be attainable (5 and 6). As the result of a critical examination of a considerable nursery bed of one and two year old trees grafted upon such standardisation root stocks, a preliminary arrangement of these root stocks into four more or less distinct groups was then hazarded.

Observations made upon small units of two year transplanted trees seemed to strengthen these conclusions (1).

The Experimental Material and its Treatment.

A second stage has now been reached in these investigations, which makes it possible to estimate accurately how far these early deductions have stood the test of years, and to what extent they are of importance.

In order to test the nature and amount of influence exerted by the root stock upon the scion, in the winter of 1918-19 approximately 127 one year grafted apple trees of the variety Lane's Prince Albert were planted out, at a distance of fifteen feet apart. In the following winter, a further 306 one year budded trees of the same variety were added. The land had been uniformly cropped and manured for five years previously and was believed to be uniform.

All the stocks and trees were raised in the Station's experimental nursery, the buds and grafts being taken from a few selected trees. From the outset, every care was taken to ensure comparable cultural treatments for all the

trees, which were uniformly headed at two feet in order to make bush trees. All the trees, the records from which are here to be discussed, were pruned annually according to a fixed rule. The extension of branches, or "leader" growths, were limited in number and tipped annually, a fixed proportion of the new wood being removed throughout. All lateral growths, or secondary shoots, beyond a fixed length, were shortened to five well developed buds, all others, unless they crowded the centre of the tree, being allowed to remain.

Problem of Numbers and Distribution.

Whilst the very nature of the material under experiment limited the number of individuals, the possibilities of random distribution, and annual repetitions of plantings, the evidence available seemed to suggest the unreliability of experiments based on very small units. Since no published evidence was available to show the limits of variability which might be expected from tree to tree with such material, two very different plans were adopted in the succeeding seasons. In 1918-19, ten trees on each variety of root stock were planted in two groups of five, each running consecutively in numerical order, but since half were left entirely unpruned, it is not proposed to deal with these in detail here, the records taken not being capable of accurate comparison, with the five pruned trees. The unit on this plot must therefore be regarded as only five trees, though, in actual fact, the behaviour of the unpruned trees does go to confirm the deductions drawn from the pruned series.

Repetition in Successive Seasons and on Different Soils.

In the winter of 1919-20, planting on a much larger scale was carried out, units of twenty trees on each root stock being aimed at. These units were distributed, as far as possible, in at least four situations on the plot. This was just as well, since it is now known that the soil is not so uniform as was at one time imagined.

During this same winter, smaller units of trees, varying in the main from five up to ten, were planted on four other widely different soils, and, as far as practicable, were kept under similar management and observation.

Parallel Tests of Stock Influence on other varieties.

Incidentally, Lane's Prince Albert was not the only variety planted in these trials. Equally extensive trials of Bramley's Seedling and Worcester Pearmain were, in all cases but one, laid out at the same time, but, at the moment, in order to keep the issue clear, it is proposed to discuss in detail the figures from the one variety only. Since Lane's Prince Albert is naturally an early maturing variety, it was selected in the knowledge that it was likely to yield earlier the most complete results.

More recently considerable areas have been planted out to test the effect of different rootstocks upon a number of other Commercial varieties, including Cox's Orange Pippin, Stirling Castle, Grenadier, Lord Derby, Newton Wonder, Allington Pippin, Blenheim Orange and Annie Elizabeth.

These trials have developed far enough to make it possible to say that, with very few exceptions, the general principles brought to light in this paper are widely applicable to these varieties also.

The Root Stocks under Trial.

On the most comprehensive plot at the Station, twenty-two varieties of root stock are actually under trial, but on most of the complementary plots it was only possible to include certain representatives of each supposed group. In this paper, the behaviour of trees upon only sixteen of these root stocks will be considered in detail. The other six varieties were seedlings selected and vegetatively raised at East Malling, and were not available in sufficient quantity as is now realised, to justify the drawing of significant comparisons. The sixteen varieties of root stock, to be dealt with here, comprised representatives of the nine varieties of so-called " Paradise " in more or less common circulation in Europe (Nos. I. to IX.), together with a number of more recently selected seedlings which had been multiplied vegetatively (Nos. X. to XVI.). Despite the widespread interest in Apple Stocks manifested during the latter half of last century, to which the writings of Thomas Rivers (8) and A. F. Barron (9) bear witness, the identity and potentialities of even the " Paradise " varieties seem to have been largely forgotten when this work was initiated, if indeed their significance had ever been fully recognised. This was suggested by the fact that no less than 36 per cent. of the original sample collections, purporting to be true, contained more than one variety, whilst 66 per cent. were improperly named. The subsequent " rogueing " of commercial stool beds and identification of trade samples over a period of ten years has fully confirmed this view. The trial of the newly selected seedlings, some of which were of German origin, and others were first propagated at East Malling, represents the exploration of a new field. Since these new introductions possessed no trade names, and since the nomenclature of the commercial varieties was frequently in dispute, an identification number was given to each variety as it was described. Although the nomenclature of at least six varieties is now very generally accepted, for sake of brevity, the identification numbers alone are generally used in this paper.

It was suspected that in such a series of root stocks there might be found a range of influence that would provide trees from miniature bushes for intensive culture, to those suitable for widely spaced orchard planning, As a matter of fact, as will be seen, such a range of vigour was disclosed within the limits of the so-called " Paradise " or " dwarfing " stocks alone, though the newer selections

provided the majority of those root stocks found to impart vigour to the scion.

Nature of the Observations Made.

Since the somewhat elementary technique generally employed in estimating the results of field experiments with fruit trees did not seem to have yielded many indisputable conclusions, it was planned as far as possible to make a complete record of the whole performance of each individual tree.

(*a*) *Measurements of Vigour.*

With a view to determining each tree's growth performance, the total length of new wood was recorded annually. This involved the individual measurement of each shoot produced, and as a single tree by its seventh year may produce as many as 600 shoots and approximately 1,500 trees in all were so recorded, the magnitude of this task alone can be gauged.

The size of the tree's head was recorded by taking the average height and spread of branches (in two directions) for each tree. Incidentally, this observation affords an indication of the space required for normal development on each variety of root stock.

These two measures of growth, however, are not complete in themselves, since they give no indication of the annual increment of the thickening of stem and branches. The simplest method of making this observation appeared to be to measure stem girth at a fixed point annually. Such a record is translated into practical terms when the capability of the tree for bearing heavy crops of fruit has to be considered.

(*b*) *Measurement of Tree's Productivity.*

In taking a measure of the tree's productivity, it was decided for two reasons not to rely solely on the ultimate number or weight of fruits harvested. As yet, the importance of fruit bud formation (as apart from fruiting), in relation to the tree's ultimate growth and cropping, is not fully understood. Therefore an annual count of all blossom trusses was made, and they were classified according to their position. Since it was realised that so many disturbing factors, such as weather, stood between the bloom and the ultimate crop, not only was this precaution taken, but, in the early years, the fruits were counted almost immediately after setting, and finally counted, weighed and graded when ripe.

Numerous other observations such as the date of blossom opening, the incidence of disease, the root-hold and suckering of the tree, were made. It is not intended to deal with these in detail here, though many of the results (10) are as worthy of consideration as some of the strictly numerical data which will now be presented.

DISCUSSION AND ANALYSIS OF THE RECORDS.

Table I. summarises the first seven seasons' growth measurements of Lane's Prince Albert on the largest Plot at East Malling.

TABLE I.

Indications of Stock Influence upon Vigour of Lanes' Prince Albert Apple (First seven seasons, 1919-26).

AVERAGE MEASUREMENTS.

Stock Identification No.	No. of Trees.	Total Wood Growth in metres per tree. With Standard errors.	Height in cms. 1925–6.	Spread in cms. 1925–6.	Girth in mms. 1925–6.
IX.	**20**	**46.9** (± 3.6)	**132**	**176**	**109**
VIII.	8	66.0 (± 6.7)	162	192	117
III.	19	101.4 (± 7.4)	204	206	175
II.	**20**	**109.2** (± 7.8)	**203**	**222**	**178**
V.	20	114.1 (± 5.9)	228	230	186
XI.	9	126.0 (± 5.6)	230	250	192
X.	20	133.8 (± 5.8)	231	241	199
XIV.	8	145.5 (± 8.9)	239	250	196
VII.	19	148.8 (± 6.7)	227	249	190
I.	**20**	**159.2** (± 7.4)	**242**	**245**	**207**
XIII.	20	160.8 (± 7.9)	257	266	209
VI.	20	163.3 (±10.8)	246	258	214
XV.	18	175.4 (± 9.1)	253	258	210
IV.	9	201.1 (± 9.7)	252	268	212
XVI.	20	220.3 (±10.5)	276	276	224
XII.	**29**	**233.2** (± 8.2)	**275**	**278**	**237**

Column 1 gives the identification number of each variety of root stock. (These numbers in themselves bear no other significance.) The varieties of root stock are arranged in order of vigour as expressed by the total wood growth, given in column 3.

VIGOUR AS EXPRESSED IN WOOD GROWTH.

It will be seen at once that the trees on stock No. XII. average nearly five times the wood growth of those on No. IX. It might appear to be hardly necessary in such a case to apply statistical methods to prove that such a difference is a significant one. In actual fact, in this case, the odds against such a difference being due to chance are enormous. However, when the intermediate averages are examined, it will be seen that there exists, with one definite break, a very regular gradation of wood growth extending from approximately 100 metres up to 230. If, however, any two closely adjacent series of trees are compared, it is difficult to tell whether the difference between the averages is a real one or only due to chance, unless recognised statistical tests for significance are employed.

In this paper a difference between the averages of two varieties is not regarded as significant unless the odds against such a difference being due to chance are more than thirty to one. Such odds are obtained when the actual difference is more than three times the standard error of the difference.*

Four Significantly Different Stages.

Whilst this criterion actually shows no absolute dividing lines in this series, with the exception of that which clearly separates stocks Nos. IX. and VIII. into a group by themselves, it also shows that such widely separated stocks as Nos. IX., II., I. and XII. (indicated by block type), are really different, and bears out the forecast made on slender evidence in the early stages of the experiment. From a theoretical standpoint, these four stocks illustrate four significantly different phases of the tree's performance, and, though other examples could be discussed in detail, it seems opportune to concentrate attention mainly upon those four varieties. Moreover, since these four root stocks probably represent the best selection available to-day for commercial purposes (11), there is also a practical utility in emphasising these four distinct stages, especially since these differences are, beyond dispute, of a definite nature. Yet, whilst from a practical point of view, it is expedient to try and group the other root stocks around these four types, it must be remembered that, strictly speaking, these other varieties really fill up the intermediate gaps.

An almost Continuous Gradation of Vigour and its Seasonal Modification.

The brackets given in Column 3, Table I., indicate the groupings and overlappings of the trees on the various root stocks, according as the apparent differences between the averages mean anything or not.

The only group which has no connecting link with the others is the very dwarfing one, comprising Nos. VIII. and IX. It is of course probable that, if in the matter of initial stock selection it had been possible to spread the net wider, not only might this gap have been bridged, but stocks extending the range of vigour in both directions might have been found.

The breeding work now in progress, in collaboration with the John Innes Horticultural Institution, suggests these possibilities. On the other hand, this very dwarfing group is proving so unique in behaviour in many ways from the rest of the series that, at least from a scientific point of view, it deserves very special attention.

* e.g. : Actual difference between mean wood growths of trees on

No. IX. and those on No. II.	= 62.3
S.E. of IX.	= 3.6
S.E. of II.	= 7.8
S.E. of difference	= 8.6 approx.

Actual difference=over seven times S.E. of Difference ; the odds against this difference being due to chance are very great.

Although, in the other groups, during the six seasons of growth since planting there have been few radical changes in the relative order of vigour, trees on several of the stocks, whilst exhibiting small apparent differences, actually fluctuate around the group type from year to year.

This is well shown in Appendix A and Diagram A (Plate II.) by the performance of trees on such stocks as Nos. VI. and XIII. Whilst the one (VI.) has caught up and passed some of its earlier companions, the other (XIII.) has slowed down and been equalled in wood growth by stocks originally starting much more slowly.

The most radical change is that of the trees upon No. X. which, up to the end of the third year, came third in order of vigour on the list, and have now sunk to tenth place. In most cases the reaction between crop performance and growth seems to offer the most probable explanation for these phenomena. In others, rapidity of recovery after transplanting might afford an explanation.

The comprehensiveness of the range of vigour found amongst the so-called Paradise or Dwarfing Stocks in commercial use was somewhat surprising. One of the most unexpected cases of vigour, and one to which it will be necessary to refer again as being of especial scientific interest, is No. IV., the Holstein Doucin—a variety in wide commercial circulation in Europe as a dwarfing stock. Though in stature the unworked stock is practically as dwarf as No. IX—the Jaune de Metz Paradise—and frequently sold in mistake for it, it produces trees making nearly four times the wood growth and occupying about three times the space of those worked upon the latter stock. On the other hand, it differs notably in several very important respects from other members of the very vigorous group of stocks in which it must be included.

Whilst it is unfortunate that a larger unit of trees on this stock was not available for inclusion in the experiment at the time, the trees on No. IV. have behaved in an exactly similar way on other soils, so that its record can confidently be considered as typical. Dwarf in nature, surface rooting in habit, manifesting at the point of union the typical swelling so commonly associated with the really dwarfing stocks, this peculiar variety produces a tree of great vigour, and, as will be seen later, comparatively early productivity. Unfortunately, a poor root hold, and a bad record in the nursery for refusing to "take the bud" debar it from occupying commercially a unique position.

Size of Tree as expressed in Height and Spread.

Columns 4 and 5, Table I., give an alternative expression of vigour in the average Height and Spread. If these figures are examined in relation to the complementary total wood growth, it will be readily seen that in nearly all instances the two are highly correlated. On the other hand, the alteration in the actual shape of tree, on such stocks as Nos. IX., and VIII., VII. and II. and,

XI. and IV. (which instead of being approximately equal in height and spread like the others, are considerably wider than high), might never have become apparent, were it not for these supplementary records.

It will moreover, be realised that the record of space filled by the tree is of prime economic significance. (See Diagrams C to H on page 10, correlating this with crop performance.)

Girth of Stem.

Column 6, giving average girth in 1925-6 at a fixed point, is an expression of the "sturdiness" of the trees, and here again the differences shown, by comparing the four groups, are all significant, and there appears a close correlation between this record and our other measures of vigour.

Table II.

Indications of Stock Influence upon Productivity of Lane's Prince Albert Apple (1919-1925).

Stock Identification No.	No. of Trees.	Average per tree. Total No. of Fruit Spurs. Formed 1923 to 1924	Average Total Number of Fruits.		Per cent. Blossom Set.			Average.
			To 6th Year (1924)	To 7th Year (1925)	1923	1924	1925	
IX.	**20**	**231**	**61**	**112**	3	15	11	9.7
VIII.	8	214	36	85	2	21	9	10.7
III.	19	175	14	50	1	15	6	7.3
II.	**20**	**195**	**21**	**66**	1	15	8	8.0
V.	20	143	11	51	2	9	8	6.3
XI.	9	116	9	68	3	12	13	9.3
X.	20	174	11	69	2	13	8	7.7
XIV.	8	132	1	34	1	2	6	3.0
VII.	19	265	32	105	2	12	8	7.3
I.	**20**	**160**	**11**	**65**	1	12	9	7.3
XIII.	20	104	4	38	1	7	8	5.3
VI.	20	120	11	40	2	9	7	6.0
XV.	18	62	4	31	2	15	10	9.0
IV.	9	137	15	73	4	16	12	10.7
XVI.	20	54	1.5	17	1	7	7	5.0
XII.	**29**	**49**	**0.5**	**10**	1	4	4	3.0

The Productivity of the Tree.

Table II. gives in brief the other side of the picture up to date, i.e., Stock effect on productivity. Although the varieties of stock are still arranged in the order of their wood growth, it is at once noticeable that if productivity were taken as the criterion, with here and there an exception, the order would be almost exactly reversed. Whilst the dwarf trees on No. IX. have produced on the average 112 fruits each to date, the very vigorous trees on No. XII. have produced only 10, and the intermediate sized ones on Nos. II. and I. have

borne respectively 66 and 65 apiece. This seems to bear out the oft repeated saying that growth and fruiting are antagonistic. But, if some of the exceptions in Table II. are studied, it will be obvious that this conclusion at least needs modification. For instance, trees on No. VII. are ninth in order of vigour, and would be placed in the vigorous group, yet they have produced 104 fruits apiece on the average, a performance which ranks them with the very precocious stocks.

Again, the very vigorous trees on No. IV. have produced 73 fruits apiece, whilst their companions in vigour have produced only 31, 17 and 10.

It is quite obvious that whilst certain varieties of root stock may be, to all intents and purposes, identical in vigour, they may be far apart in the matter of productivity. For instance, trees on Nos. XIV., VII., I. and XIII., are bracketed together for vigour, yet their respective productivity is 34, 105, 65, and 38. Stocks numbers VII. and I. are significantly different from each other and also from the other two varieties in point of cropping. These are matters of prime importance to the tree planter and to the experimenter, for if trees so similar in vigour and form can give consistently such widely different yields, tree selection, from a root stock point of view, becomes a matter of the greatest importance.

EARLY PRODUCTIVENESS.

Table II. by itself does not tell the whole story of the productivity of these different series of trees, though column 4, showing the total fruits to the sixth season, does give the hint that in the earlier individual years the differences in productivity were even greater. Appendix B and Diagram B (Plate II.) show what the situation has really been, and how the trees on stocks such as Nos. IX. and II. started to produce fruits very quickly and give an early return on capital, whilst trees on other stocks, such as Nos. I. and X., though they are now catching up to these more precocious bearers, have done so almost entirely on one season's crop.

PRODUCTIVENESS IN RELATION TO SIZE OF TREE.

If Appendices and Diagrams A and B are studied side by side, the relationship between cropping and amount of wood growth can be clearly traced. But there is yet another aspect of this question to consider, i.e., the amount of crop borne upon the possible cropping area. A measure of the relative sizes of the tree's heads has already been given in the figures for heights and spreads, but, when these are considered in relation to the actual crops borne, the contrast becomes even greater.

Diagrams C to H, Plate I., show this pictorially. Whilst C, D, E and F illustrate the expected relationships between growth and fruiting of the four groups, G, which differs little in size from F, shows a much greater early fruiting capacity, and H, similar in size to E, almost rivals C in the number of fruits borne.

PLATE I.

CROPPING OF LANE'S PRINCE ALBERT ON DIFFERENT STOCKS IN RELATION TO SIZE OF TREE.

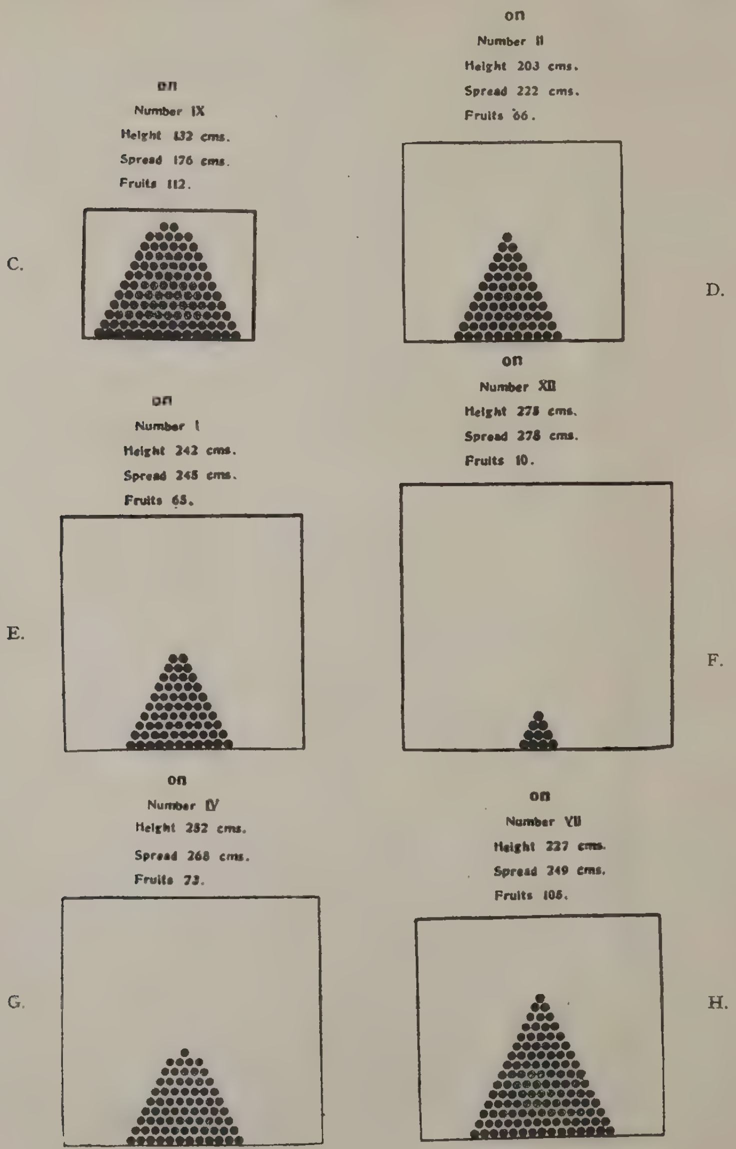


PLATE II.

Diagram A.

COMPARING ANNUAL WOOD GROWTH OF TREES ON VARIOUS ROOT STOCKS

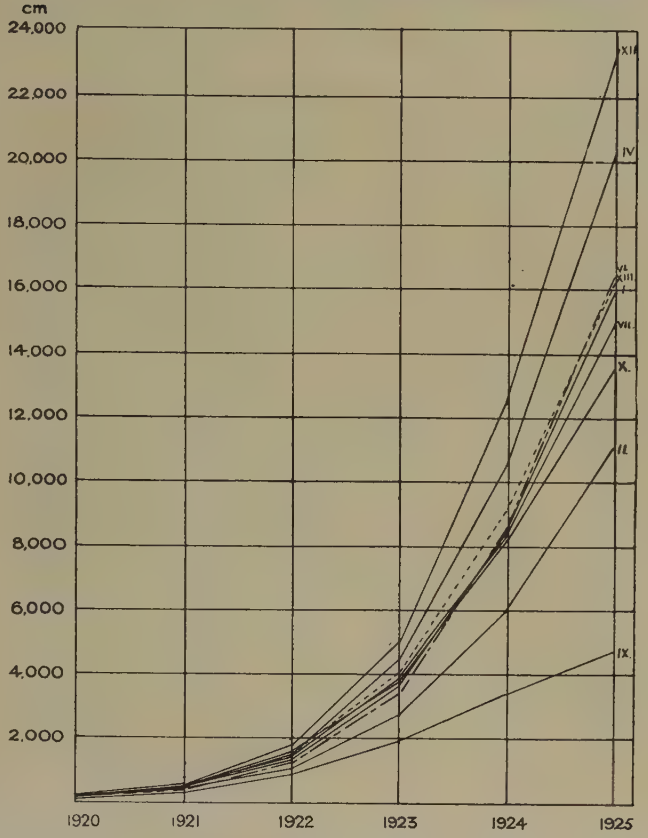


Diagram B.

COMPARING ANNUAL FRUITING OF TREES ON ROOT STOCKS

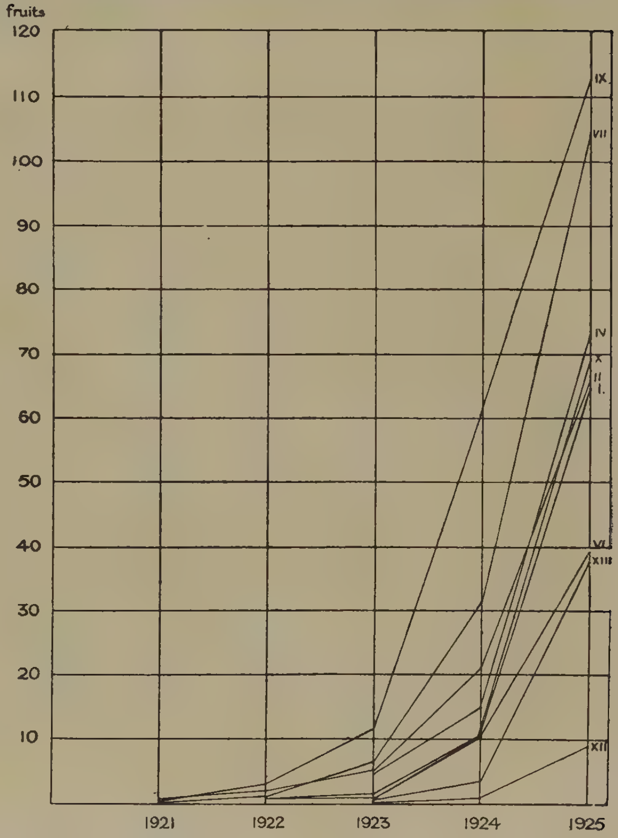
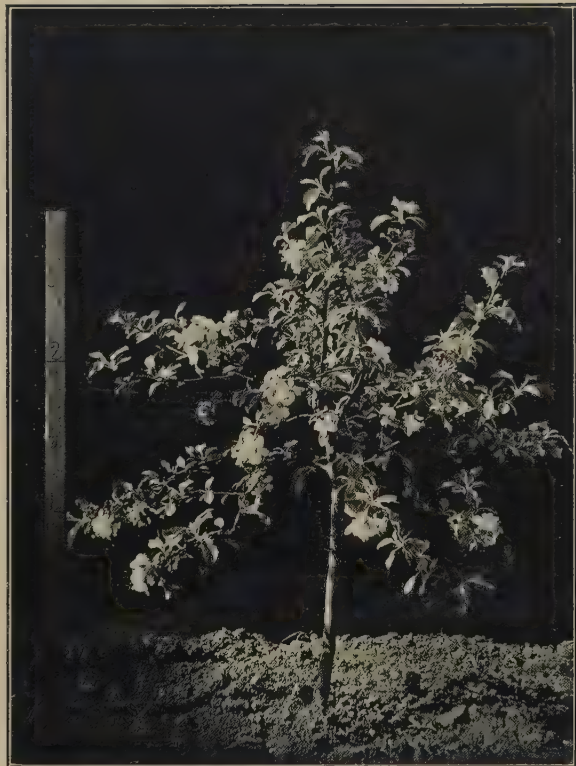


PLATE III.

On Broadleaf (No. I.) at 4 years old.



On Jaune de Metz (No. IX) at 4 years old.

Two Average Trees of Lane's Prince Albert.

Plate III. shows the general contrast between an average tree on the Broadleaf No. I. stock, and a similar tree on the Jaune de Metz No. IX. Besides the amount of wood growth, thickness of stem and quantity of blossom, the difference in the actual habit of the two trees of a single variety is very striking.

TABLE III.

Estimated rate of Cropping of Lane's Prince Albert Tree in Bushels per acre.

	On Stock.			
	No. IX.	No. II.	No. I.	No. XVI.*
Possible Number of "fillers" per acre.	504	268	150	101
1920 2nd year†	Nil	Nil	Nil	Nil
1921 3rd ,,	35	13	Nil	Nil
1922 4th ,,	71	21	4	Nil
1923 5th ,,	130	54	22	3
1924 6th ,,	357	200	126	29
1925 7th ,,	530	302	150	120
Total Yield	1,123	590	302	152 bushels

The same point has been made elsewhere for the fruit grower in tabular form (12), and since the table combines the idea of size of tree with that of earliness of coming into bearing it seems justifiable to reproduce it here in Table III. It may also be of assistance to the Research Worker in selecting the populations for his field experiments.

PERCENTAGE OF BLOSSOM SETTING.

Nothing has so far been said about the last columns (Nos. 6 to 9) of Table II.—the percentage of Blossom set. Though in actual fact it has only been possible to count the number of trusses on each tree, it has been possible to check the fact that the average number of flowers per truss does not vary greatly on different stocks. It has, therefore, been possible to get an approximate idea of the actual number of flowers which ultimately produced fruit. That there are notable differences between the four representative stocks is certain. These differences have been more or less consistent from year to year, and they have repeatedly occurred upon plots planted in successive years and on different soils. At the moment the causes for the better setting on Nos. IX. and VIII., for instance, are not ripe for discussion, but the fact is one likely to arouse speculation.

* The figures in this table were calculated from Plot X. where Stock No. XII. was not represented. But since No. XVI. is not significantly different in growth or cropping from No. XII., it is here substituted.

† i.e., from planting as Maiden Trees.

Varying Position of Fruit Buds.

Earlier in this paper, it was stated that the position of the fruit buds was noted on each tree, and that the buds were classified into Terminal Fruit buds, i.e., those at the extreme tip of Annual Growths ; Axillary fruit buds., i.e., those elsewhere upon year old wood ; and Spurs, i.e., those that had taken two years or more to develop into short spur-like growths. Suffice it here to say that trees upon the most differing varieties of stock yielded very different results. Whilst axillary fruit buds were a notable feature on No. IX. in the early years, and also to some extent on No. II., they were found infrequently on No. I., and still more rarely on No. XII. up to the sixth year. In the early years the fruit buds on these latter stocks were confined largely to the terminals. The details are summarised in Appendix F.

Some preliminary figures as to the size, colour and quality of the fruit from the different stocks have already been published (7). Others are now available to demonstrate that stock influence is a real factor in this matter, if not an entirely consistent one from season to season.

Measure of Variability of Trees on Single Variety of Stock.

Although this more exact knowledge of the influence of root stock has made possible a very much greater control of the tree than heretofore, there is still some measure of individuality from tree to tree, within any one group. Whilst a whole group may show the " group character " of being dwarfed and precocious in fruiting, or very vigorous and slow to crop, there remains some individual variation.

The four diagrams, K, L, M and N, Plate IV., give for the four outstanding stocks the actual vigour of each individual tree, the height of each column representing the total amount of wood growth, and its width the girth. The trees are placed in order of size in each group. This arrangement from the least to the most vigorous assists the eye in measuring the differences. On the other hand, if the trees were arranged according to the groups in which they were planted on the ground, the cause of variations in many instances would be fairly obvious. They coincide with soil differences.

Four similar diagrams, O, P, Q and R, Plate V., have been prepared in which the height of the column represents the total number of fruits. This time the trees are rearranged in the order of their productivity.

The question naturally arises as to whether these variations can be explained by a correlation of growth and fruiting. In order to test to what extent this is true, the fruiting performance of all the trees on Nos. IX. and II. was rearranged to correspond with each tree in the vigour diagrams. It was found that in the case of trees on No. II. there is apparently no connection between vigour and fruiting, but there are indications that those trees on No. IX. show some

PLATE IV.

ILLUSTRATING INDIVIDUAL GROWTH PERFORMANCE OF EACH TREE WITHIN THE FOUR GROUPS.

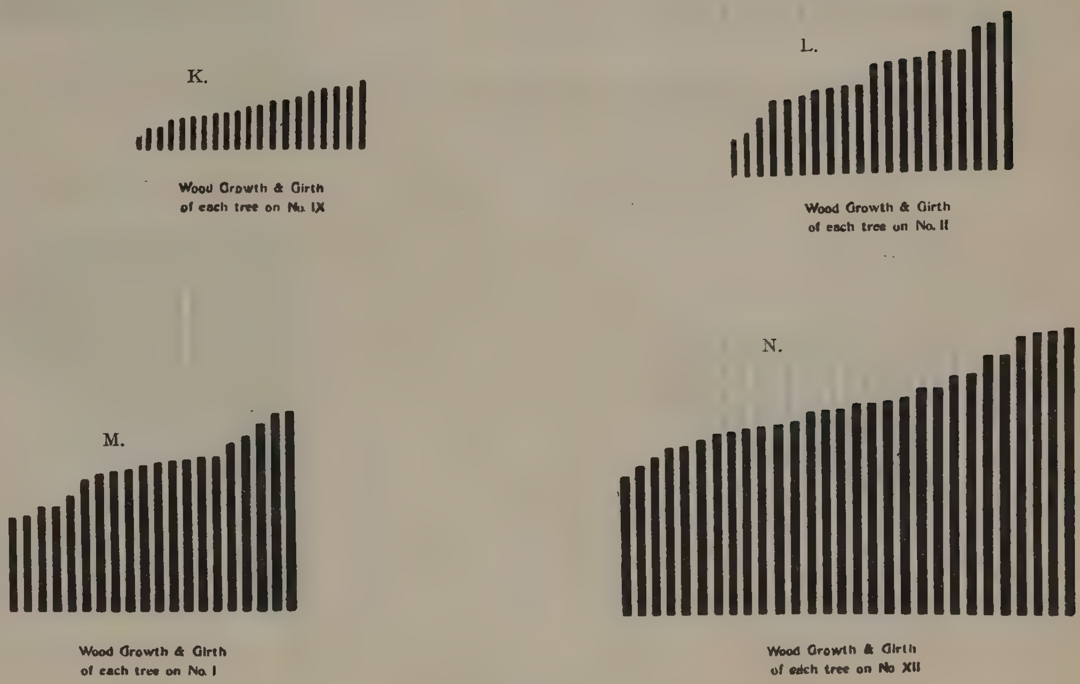
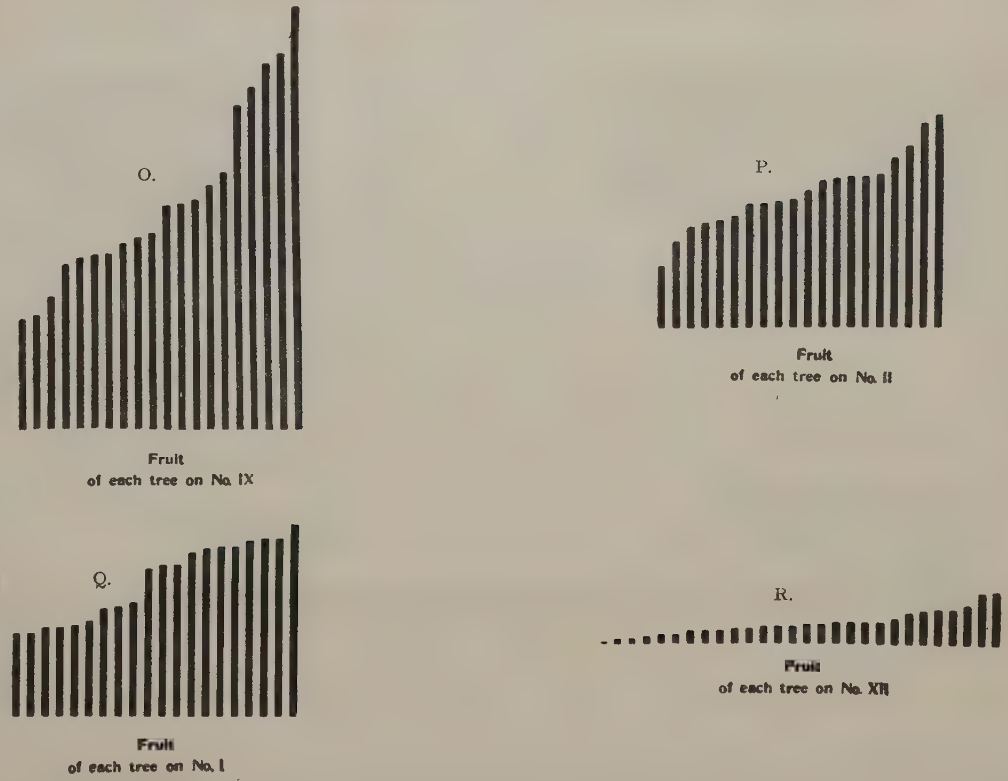


PLATE V.

ILLUSTRATING INDIVIDUAL CROPPING PERFORMANCE OF EACH TREE WITHIN THE FOUR GROUPS



positive correlation in this matter. While this is open to some doubt, it is at any rate apparent, in this case, that the four largest trees on this type of root stock have undoubtedly borne the most fruit.

CAUSES OF THE VARIABILITY.

It is not possible to do more here than indicate some of the causes of variability that have become more manifest as the investigation proceeded. From the experimenter's point of view a closer grading of the root stocks in the Nursery, and, subsequently, a more rigid choice of Maiden trees, selected individually by weight, would undoubtedly ensure even greater uniformity.

Unavoidable damage in cultivation, the effects of intercropping and the ravages of pests, are sources of disturbance. The two most potent causes of variability, however, are less under control; these are local soil differences, and the reflection in growth of the biennial bearing habit of apple trees. It is intended at a later date to trace out the influence of these factors upon these series of trees. The work already done in this direction is very suggestive. However, from the fruitgrower's point of view, the measure of control already obtained over the tree is probably economically sufficient, and even the experimenter can now obtain material of marked uniformity in comparison with that which was available generally heretofore.

TABLE IV.

Comparison of Behaviour of Successional Plantings of Lane's Prince Albert, at East Malling.

Identification No. of Stock.	Average Growth in cms. 6 years.				Relative order of vigour.	
	Unit of Trees.	Plot XI. 1920–26.	Unit of Trees.	Plot X. 1919–25.	Plot XI.	Plot X.
IX.	(20)	**4,696**	(5)	**10,343**	**1**	**2**
VIII.	(8)	6,603	(2)	8,959	2	1
III.	(19)	9,934	(5)	12,382	3	4
II.	(20)	**10,916**	(5)	**15,980**	**4**	**7**
V.	(20)	11,408	(5)	12,680	5	5
XI.	(9)	12,609	(3)	17,735	6	10
X.	(20)	13,382	(5)	15,887	7	6
XIV.	(8)	14,559	(3)	18,058	8	11
VII.	(19)	14,855	(4)	11,243	9	3
I.	(20)	**15,930**	(4)	**21,907**	**10**	**13**
XIII.	(20)	16,084	(5)	21,880	11	14
VI.	(20)	16,318	(5)	17,648	12	9
XV.	(18)	17,601	(4)	19,309	13	12
IV.	(9)	20,106	(3)	17,457	14	8*
XVI.	(20)	**22,011**	(4)	**26,885**	**15**	**15**
XII.	(29)	23,332	No trees.		16	—

* These trees were not comparable with the rest of the series. The grafts failed so badly on this stock that it was not possible to select good average trees.

Corroboration of Results obtained from other Plantings.

As already stated, five other plantings of smaller sets of trees were made. One of these plots was planted out a year earlier on similar adjacent soil at East Malling, the other four on very different soils in other parts of the country.

Table IV. shows the behaviour of the trees, as regards wood growth, on the two successional plantings at East Malling, when they had both made six years' growth. Although it is obvious that either seasonal, planting or soil conditions have very much favoured the growth of the trees on the earlier planted plot X., it will be seen that the *relative* order of vigour on the four main stocks is still maintained, with remarkably large differences between them. It is interesting to note how the trees on No. IX. in Plot X. approximate to those on No. II. of Plot XI., those on No. II. on Plot X. to those on No. I. on Plot XI., and so on. This illustrates very well how comparatively small differences may alter the *actual performance* of trees on particular stocks, though *not their relative position.*

Considering the small unit of pruned trees (on Plot X.) available for comparison with those on Plot XI., it is indeed even more remarkable how few of the intermediate series have changed their places very radically.

Table V.

Showing similar Indications of Stock Influence upon Vigour on smaller Unit of Trees Planted a year earlier. (Plot X.)

Stock Identification No.	No. of Trees.	Average Wood-Growth in Metres. To 1924.	Average Wood-Growth in Metres. To 1925.	Height in cms.	Spread in cms.	Girth in mms.
VIII.	2	89.6	—	218	248	175
IX.	**5**	**103.4**	**142.1**	**209**	**274**	**164**
VII.	4	112.4	—	229	270	201
III.	5	123.8	—	248	261	222
V.	5	126.8	—	278	285	240
X.	5	158.9	—	267	310	247
II.	**5**	**159.8**	**241.4**	**263**	**301**	**244**
IV.	3	174.6	—	285	305	250
VI.	5	176.5	—	270	310	258
XI.	3	177.4	—	270	320	252
XIV.	3	180.6	—	300	314	250
XV.	4	193.1	—	298	315	262
I.	**4**	**219.1**	**305.5**	**274**	**347**	**272**
XIII.	5	218.8	323.6	329	355	278
XVI.	**4**	**268.9**	**434.0**	**338**	**386**	**296**

Table V. gives the other accumulated records for the smaller plot. Appendices C and D give the records from year to year in greater detail. If these be compared with the similar observations from Plot XI. (Table I.) and Appendices A and B, it will be seen how closely the behaviour of the one planting follows the other. Though the performance, as expressed by vigour,

of the trees on Plot X. is almost exactly " a stage " better, in that the growth of the trees on No. IX. equals the growth of the trees on No. II. from Plot XI., and so on, the relative behaviour is unchanged.

The results obtained on the other soils confirm this once again, and though there are amazing differences in the *actual* performance of the trees due to local factors, the *relative* performance has been identical. The records from these plots have recently been summarised (12) and their practical bearing indicated, but in order to complete the picture of this portion of the investigation Table VI. is given.

The wide differences in soil texture are shown in Appendix E, which gives comparative mechanical analyses.

Table VI. illustrates the comparative behaviour of the sets of trees on representatives of the four principal groups of stocks on the five different soils. Whilst a detailed discussion of each individual plot must be left to another occasion, it will readily be seen how generally the conclusions drawn from the Malling plots are confirmed.

Though it remains to test the *actual* behaviour of similar series of trees upon many other types of soil and in various climatic conditions, it can fairly be claimed that this investigation has resulted in the establishment of a constant relative standard of performance.

Further, an almost indefinite series of scion varieties remains to be tested on the various stocks. However, similar records to those here presented have already been accumulated for six other scion varieties, and, although when the full analyses of these are published, some interesting new facts will be brought to light, the general lines of stock effect on vigour and productivity here laid down will be found to be maintained. It has elsewhere been indicated to the grower how he can make use of this information so as to select his trees upon root stocks suitable for different soils, varieties and purposes (12).

It only remains to suggest that since a more precise knowledge is now available for the experimenter as to the nature of the material he has to work with in the field, it should be possible, for given sets of conditions, to arrive, much more accurately, at the necessary units of trees required to show given differences. In the investigations here detailed, it is now realised that the differences which they were designed to discover were actually very large, yet if the same experiments were set out again to-day the causes of variability could undoubtedly be still further reduced, and so the unit of trees lessened.

On the other hand horticultural science is still in its infancy, and its investigators are as yet out to measure fairly large differences; but the time is not far off when they will want to discover smaller differences, and then the more highly controlled their material, the more likely will be their experiments to yield significant results.

TABLE VI.

	Average Total Growth a.					Average Total Cropping Figure for 5 years.					Average Total Cropping Figure for 6 and 7 years.				
	Malling.	Swanley.	Wisley.	Wisboro'.	Tunstall.	Malling.	Swanley.	Wisley.	Wisboro'.	Tunstall.	Malling.	Swanley.	Wisley.	Wisboro'.	Tunstall.
	Medium loam.	Gravel loam over chalk.	Sand.	Heavy Clay.	Clay with Flints.	M'd'm loam.	Gravel loam over chalk.	Sand.	Heavy Clay.	Clay with Flints.	M'd'm loam.	Gravel loam over chalk.	Sand.	Heavy Clay	Clay with Flints.
GROUP.	8 yrs.	8 yrs.	7 yrs.	7 yrs.	7 yrs.	5 yrs.	5 yrs.	5 yrs.	5 yrs.	5 yrs.	7 yrs.	7 yrs.	6 yrs.	yr s.	6 yrs.
A. Dwarf (IX.)	14,312	2,615	316	‡ No Trees	‡ No Trees	37	39	60†	‡ No Trees	‡ No Trees	146	74	34	No	Trees.
B. Semi-dwarf (II.).. ..	24,232	9,533	578	2,714	1,782	26	29	84†	33	1	119	71	40	—	—
C. Vigorous (I.)	30,666	13,684	681	4,361	2,342	17	14	13†	26	0	98	96	28	—	—
D. V. Vigorous XIII. to XVI and Long Ashton 5. ..	43,499	10,591*	2,485	3,470*	‡ No Trees	5	6	2†	18	No Trees	153	33	10	No	Trees.

* Owing to shortage of trees on these stocks at time of planting, the maidens here could not be so carefully selected, and second grade trees had to be planted which were not strictly comparable.

† These figures are not strictly comparable with the other columns, since they represented the average number of blossom spurs, and not the actual fruits set, as in the other columns.

‡ Sufficient trees of Lane's Prince Albert on these groups of stock were not available for these plantings, but similar results, with trees of Bramley's Seedling and Worcester Pearmain on this soil, bear out the general conclusions.

Meanwhile, working upon a rather high estimation of the standard deviation (in order to include with safety those varieties whose variation is above the average), calculated from the records of wood growth upon the largest series of trees in these investigations, it has been possible to draw up a Table giving some sort of an indication as to the number of trees which might safely be recommended for use under similar conditions in order to show certain degrees of difference for this particular observation, i.e., total wood growth. Table VII. puts forward such a suggestion and is calculated from this estimation of the standard deviation.

TABLE VII.

The Number of Trees it is necessary to plant in order to prove differences between means.

To Show a Difference Between two Means of:	Number of Trees Required.
1%	8,520
2%	2,130
5%	340
10%	85
15%	38
20%	21
25%	14
30%	9
50%	3

A similar table could be worked out for other sets of observations, such as girth measurements or crop records, and doubtless the number of trees required would differ in each case; however the wood measurement figures were chosen as representing neither the least nor most variable set of records.

The actual experience at East Malling in these experiments has been that with sets of approximately twenty trees on each variety of root stock, it has been possible to prove differences of from 20 per cent. to 25 per cent. between means.

It is confidently hoped that, as a result of yet more careful methods of manipulation, it will be possible to produce material capable of showing finer differences.

Finally, the writer wishes to acknowledge with gratitude the help of all those who have been associated with him in these experiments. Unfortunately the very magnitude of the plan makes it impossible to mention by name all those who have assisted in collecting the observations year by year. The work of these observers is none the less valuable, and it is fully appreciated.

Mr. J. Amos has been intimately associated with the experiment from its inception, and Mr. A. W. Witt, by producing the material, made these considerable plantings possible.

The bulk of the work of computation, and the assembling of the records, fell upon Miss A. D. Mackenzie, and her assistants, Miss M. Gillman and Miss G. Blinkhorn.

Mr. T. N. Hoblyn was responsible for examining the figures statistically and Mr. M. Tydeman executed the diagrams.

The present paper has only been made possible by the wholehearted co-operation and meticulous care of the present and past pomological stafi oi the station.

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APPENDIX A.

Average Total Wood Growths for each year separately—in cms.
Lane's Prince Albert Apple. Plot XI.

Stock Identification No.	No. of Trees	Order	1920 Growth	Order	1921 Growth	Order	1922 Growth	Order	1923 Growth	Order	1924 Growth	Order	1925 Growth	Order	Average Total Growth
IX.	20	2	80	2	241	2	578	1	1030	1	1379	1	1387	1	4696
VIII.	8	1	68	1	201	1	516	2	1250	2	1817	2	2751	2	6603
III.	19	8	117	3	259	3	637	3	1516	3	3053	3	4561	3	10143
II.	20	6	110	4	277	4	632	4	1679	4	3323	4	4896	4	10916
V.	20	9	116	7	315	5	767	5	1777	5	3482	5	4953	5	11408
XI.	9	4	98	8	324	6	844	6	1999	6	3992	7	5352	6	12609
X.	20	15	156	14	389	13	1097	8	2214	7	4451	6	5075	7	13382
XIV.	8	3	87	6	288	7	854	11	2372	10	4944	8	6013	8	14559
VII.	19	11	134	11	365	10	1034	10	2352	8	4576	9	6394	9	14855
I.	20	10	132	9	354	9	941	9	2303	9	4790	11	7410	10	15930
XIII.	20	16	162	12	369	12	1074	12	2400	11	5035	10	7045	11	16084
VI.	20	7	112	5	283	8	897	7	2149	12	5055	12	7823	12	16318
XV.	18	14	143	10	362	11	1042	13	2524	13	5260	13	8214	13	17545
IV.	9	5	104	13	371	12	1063	15	2921	14	6165	14	9481	14	20106
XVI.	20	12	135	15	401	15	1113	14	2900	15	6531	15	10931	15	22011
XII.	29	13	140	16	429	16	1250	16	3219	16	7336	16	10958	16	23332

APPENDIX B.

Average Total Crops for each year separately.—No. of Fruits.
Lane's Prince Albert Apple. Plot XI.

Stock Identification No.	No. of Trees	1920	1921	1922	1923	1924	1925	Average
IX.	20	—	.25	3.35	8.35	48.95	51.3	112
VIII.	8	—	.4	1.5	8.0	25.75	49.75	85
III.	19	—	.15	.15	1.85	11.8	36.3	50
II.	20	—	.4	1.25	3.6	15.45	45.4	66
V.	20	—	—	.1	2.75	8.5	40.1	51
XI.	9	—	—	—	1.4	7.3	59.1	68
X.	20	—	—	—	1.35	9.75	58.0	69
XIV.	8	—	—	—	.5	.4	33.3	34
VII.	19	—	.05	.21	7.0	24.58	73.0	105
I.	20	—	—	.05	1.4	9.4	54.5	65
XIII.	20	—	—	—	.25	3.6	33.8	38
VI.	20	—	—	.05	2.0	8.7	28.9	40
XV.	18	—	—	—	.5	3.1	27.3	31
IV.	9	—	—	—	5.1	9.9	57.8	73
XVI.	20	—	—	—	.3	1.55	15.45	17
XII.	29	—	—	—	.1	.5	8.95	10

APPENDIX C.

Average Total Wood Measurements for each year separately in cms., for Plot X.

Lane's Prince Albert Apple.

Stock Identification No.	No. of Trees	1919	1920	1921	1922	1923	1924	1925	Total to 1924	Total to 1925
VIII.	2	132	438	1,067	1,780	3,049	2,493	—	8,959	—
IX.	5	**157**	**584**	**1,141**	**1,940**	**3,329**	**3,192**	**3,865**	**10,343**	**14,208**
VII.	4	196	707	1,640	2,289	3,354	3,057	—	11,243	—
III.	5	191	657	1,526	2,482	3,956	3,570	—	12,382	—
V.	5	162	685	1,756	2,369	3,560	4,148	—	12,680	—
X.	5	203	794	1,961	2,943	4,985	5,002	—	15,888	—
II.	5	**160**	**720**	**1,737**	**2,708**	**4,984**	**5,671**	**8,164**	**15,980**	**24,144**
IV.	3	82	503	1,448	2,732	5,667	7,025	—	17,457	—
VI.	5	167	731	1,897	3,063	5,853	5,937	—	17,648	—
XI.	3	177	812	2,041	2,961	5,782	5,964	—	17,737	—
XIV.	3	155	751	1,910	3,239	5,688	6,315	—	18,058	
XV.	4	161	701	1,859	2,991	5,722	7,875	—	19,309	
I.	4	**240**	**930**	**2,299**	**4,172**	**6,743**	**7,523**	**8,645**	**21,907**	**30,552**
XIII.	5	213	852	2,309	3,454	6,185	8,868	10,477	21,881	32,358
XVI.	4	**219**	**917**	**2,465**	**4,375**	**7,955**	**10,954**	**16,515**	**26,885**	**43,400**

APPENDIX D.

Average Total Crops for each year separately. No. of Fruits of Lane's Prince Albert. On smaller complementary Plot X.

Stock Identification No.	No. of Trees.	1919	1920	1921	1922	1923	1924	1925	Average for 6 years.	Average for 7 years.
IX.	5	—	—	**11.0**	**13**	**39**	**112**	**155**	**175.0**	**329**
VIII.	2	—	—	4.5	13	28	93	68	139	207
III.	5	—	—	0.4	2	21	109	166	133	299
II.	5	—	**1**	**6.6**	**10**	**27**	**112**	**126**	**156.6**	**282**
V.	5	—	—	2.0	3	15	57	146	77.0	222
XI.	3	—	—	.3	4	16	138	133	158.3	291
X.	5	—	—	—	1	2	89	144	92.0	237
XIV.	3	—	.7	.3	1	7	121	134	130.0	264
VII.	4	—	—	3.5	5	30	113	149	151.5	301
I.	4	—	—	—	**8.75**	**16**	**144**	**99**	**164**	**263**
XIII.	5	—	—	—	0.2	1	40	167	41.2	208
VI.	5	—	—	0.2	2	12	119	129	133.2	262
XV.	4	—	—	—	0.2	3	33	106	36.2	142
IV.	3	—	—	1.0	6	16	70	110	93.0	203
XVI.	4	—	—	—	**.5**	**6**	**40**	**142**	**46.5**	**188**
XII.	No Trees.									

APPENDIX E.

Mechanical Analyses of the Five Soils upon which the Root Stock Trial Plots were planted.

	On Lower Greensand E. Malling, Kent.	*On Clay with Flints. Tunstall, Kent.*	*On Bagshot Beds. Wisley, Surrey.*	*On Thanet Beds. Swanley, Kent.*	*On Weald Clay. Wisboro' Green, Sussex.*
Stones in Sample	4.80 (Greensand)		Nil.	10.6 (Pebbles)	Nil.
Fine Gravel ..	3.09	1.40	4.73	1.30	0.47
Coarse Sand ..	16.86 } 60.70	0.70 } 35.00	70.65 } 95.72	9.54 } 61.96	1.45 } 15.79
Fine Sand ..	40.75	32.90	20.34	51.12	13.87
Silt	18.00	27.40	0.32	10.65	24.90
Fine Silt	8.80 } 34.25	10.10 } 52.30	0.94 } 1.88	7.90 } 30.40	35.25 } 77.45
Clay	7.45	14.80	0.62	11.85	17.30

Thanks are due to Dr. W. Goodwin, S.E.A. College, Wye; to Mr. A. N. Rawes, R.H.S. Gardens, Wisley; and to Mr. T. Wallace, M.Sc., Long Ashton, for supplying these analyses.

APPENDIX F.

Fruit Bud Summary—Lane's Prince Albert. All fruit buds on prunings and on tree after pruning.

Stock Identification No.	No. of Trees	1920	1921			1922			1923			1924			1925		
		AX	SP	AX	TER	SP	AX	TER	SP	AX	TER	SP	AX	TER	SP	AX	TER
IX.	20	133	37	14	10	61	235	93	158	1000	188	666	1045	350	1446	960	506
II.	20	89	18	12	12	53	93	217	87	947	145	191	1512	281	1426	3136	684
I.	20	0	4	1	6	1	1	86	20	671	125	126	1486	201	1568	3556	797
XII.	29	0	8	1	3	4	2	74	13	47	18	25	240	95	772	2089	1212

AX = Axillary. SP = Spur. TER = Terminal.

SUMMARY.

The conclusions to date are summarised to show that it is possible to distinguish botanically and raise vegetatively fruit tree root stocks, and so eliminate seedling variability. Experiments designed to test the influence of these different root stocks upon the variety worked thereon are described.

Some discussion follows upon:

The problem of the best size for the experimental unit and its distribution.

The repetition of the experiment in successive seasons, upon different soils, and with different scion varieties.

The sixteen varieties of root stock under trial are then briefly described.

Records designed to give a complete measure of the trees' vigour and productivity are detailed, and the figures for seven and eight year old trees giving measurements of wood growth, girth, height, spread and fruit production, are presented.

These figures show that a single variety of apple budded upon four distinct varieties of root stock behaves very differently upon each, both in the amount of wood growth it makes and fruit it produces. On one root stock it may make five times the wood growth that it does upon another; or again, it may fruit ten times as heavily.

The significance of these differences is discussed. Between the four significantly different stages, an almost continuous gradation of vigour and cropping is found upon other stocks.

The generally accepted antagonism between wood-growth and fruiting is discussed, and exceptional cases cited.

It is shown that trees may appear identical in size and form, yet may be widely apart in cropping performance.

The productivity of the trees is examined both in relation to the space occupied by the tree and the age at which it comes into bearing.

The percentage of flowers which set and form fruit has differed consistently upon different root stocks, so has the position of the fruit buds on the tree.

The amount of variability between trees upon the same root stock is illustrated, and the causes discussed. These differences are partly due to soil differences and the biennial bearing habit of the trees, and might be even further reduced.

The general results are confirmed upon the supplementary plots on very different soils, the *actual* performance of the trees on any particular stock differing much from soil to soil, but the *relative* performance remaining the same.

It is claimed that a much greater control has been established over the tree than heretofore, as a result of a more precise knowledge of the influence of root stock.

From the point of view of Horticultural Experimenters it opens up the possibility of using much more uniform material for field work. It is now possible to gauge its variability and determine more accurately the essential lay out of such experiments, with, consequently, greater hope of obtaining more significant results.

From the fruit growers' point of view the economic value of trees of known capabilities for size and cropping is demonstrated.

THE HEALING OF WOUNDS IN WOODY STEMS.

II. CONTRIBUTIONS TO THE PHYSIOLOGICAL ANATOMY OF RINGED APPLE SHOOTS.

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Introduction.

In a previous paper upon the same general problem (12), the results of an investigation into the normal physiological factors involved in the process of closing up the end of a severed branch were presented. It was there indicated that the process was essentially one of changed physiological conditions, resulting in the production within the medullary ray cells of a viscous substance closely allied to wound gum. This gum subsequently escapes into the vessels which it fills, then it hardens and undergoes certain unknown chemical changes, the nett result being that the end of the xylem tissue is completely blocked. This development takes place only during the months of June, July and August, that is during the period of active growth. Wounds made at any other time of the year remain more or less open until early June, when they become rapidly and effectively blocked. The bearing of these results upon the practice of pruning and the prevention of fresh attacks of Silver Leaf Disease was also mentioned.

The present series of observations and experiments is an extension of the above work to the healing of wounds in woody stems, where instead of completely severing the end of the branch, a ring of cortex and phloem only is removed. This process will be subsequently referred to as ringing, although it is often called girdling, particularly in the American literature on the subject. This investigation from the standpoint of physiological anatomy is the natural continuation of the previous work, and is interesting in view of the increasing practice in commercial horticulture of ringing fruit trees in order to increase bearing. The expansion of this practice is comparatively recent, and there has grown up much diverse opinion upon its merit. Many growers are of the opinion that the practice is unnecessarily drastic. While in some cases ringing has resulted in the death of the trees, owing either to the ring having failed to heal over properly, or else to disease having gained an entry at the point of ringing, evidence is accumulating which strengthens the idea that when we know sufficient about the normal physiology of the fruit tree in question, ringing may be practised to profit. It is hoped in the present paper to add some knowledge which will render ringing more effective as a practical horticultural operation.

The investigation has also a wider interest, because it is to ringing experiments of various types that appeal is made in order to decide the relative

functions of xylem and phloem in the transport of organic substances, particularly carbohydrates, about the plant. Dixon (4) in objecting to ringing experiments as a means of establishing the function of the phloem in translocation, contends that the outer vessels and tracheids of the exposed woody cylinder are rendered functionless by the occlusion of air bubbles, and by the development of gummy substances within them. The ground of this objection is to some extent confirmed in the present work, but other observations also recorded herein lead to the conclusion that the amount of xylem which is thus rendered functionless is insufficient to support Dixon's objection. A similar conclusion has been recently put forward by Gardner (5) in his valuable contribution to this field of study. Curtis (2 and 3) was one of the first English speaking workers to apply the ringing method to the elucidation of the problem of translocation, and much of his data has been confirmed in the present work. The significance of the results here recorded, as related to the problem of translocation, is not discussed as it is hoped to do this in a later communication when work now in hand has been further developed.

As pointed out in the previous paper, the time relationship is a very important factor when considering the effects of wounding. The present investigation brings out quite clearly that the time of ringing relative to the more or less well defined stages in growth, such as bud break, full leaf stage, and fruit bud differentiation, is extremely important. The numerous contradictions in the literature as to the effects of, and responses to ringing, are doubtless due to ringing at different stages of the seasonal plant growth. The fundamental importance of considering the different stages of growth in any discussion of such practices as manuring and pruning is now being more generally recognised.

The factors that operate in the formation and development of xylem and phloem tissues from the initial meristematic cells, are as yet not clearly understood. Pearsall and Priestley (11) have, however, recently advanced the idea that the reaction of the fluids bathing the different sides of the cambium tissue probably plays a considerable part. It is clear, however, that the meristematic cell as it is left by the cambial layer is potentially able to produce any type and shape of tissue element. The effects of ringing as reflected in the type of wood growth produced, are also presented. The effect of repeated defoliation upon the form of wood growth produced in larch trees, as recorded by Harper (6), and the results here presented suggest nutrition, particularly carbohydrate nutrition as being one of these factors.

The presentation of the data, owing to the numerous dates at which ringing was carried out, proved to be difficult, but it is thought that the following method is satisfactory. The results being grouped together and placed as far as possible under sub-headings allows of easy reference and the avoidance of repetition. The following arbitrary terms are used throughout this paper. The point of

ringing is regarded as the " datum line " ; the parts of the branch lying between the point of ringing and the apical bud will be referred to as " above the ring," whereas those situated between the ring and the ground level as " below the ring." The parts laid bare by the removal of the ring of cortex and phloem. right down to the pith, will be referred to as " under the ring."

II. EXPERIMENTAL METHOD.

The experiments were carried out at Long Ashton during the year 1925, using ten-year old apple trees of an unknown variety. Rings of cortex and phloem 1.5-2.5 cms. wide were removed from the 1922 (i.e. the two-year) parts of the branches. The ringing was done at suitable, approximately monthly intervals during 1925, commencing on February 17th. On each ringing date a sufficient number of branches were treated to allow for the collection of one or more of them at subsequent monthly intervals throughout the year.

The rings were made as carefully as the scale of practical operations would allow, particular care being taken to damage the woody cylinder as little as possible. The rings made in the earlier months (February to May) were left bare, that is they were not touched in any way after having removed the rings of cortex and phloem. Of the rings made in the later months some were covered over immediately with several layers of adhesive surgical tape, the object being to protect the wounds from drying out. Other rings made at the same time as those covered over, were left bare as in the earlier ones.

The method of histological examination was essentially similar to that employed in the previous investigation. The material as gathered was preserved in formalin-alcohol, and sections were obtained from it without embedding in paraffin by using a Jung Sliding Microtome.

III. EFFECT OF RINGING UPON WOUND GUM FORMATION.

The first ringing date was February 17th, 1925, at which time there were no superficial signs of spring growth, and the cambial tissue was so firmly united to the woody cylinder as to render effective ringing difficult to accomplish. This difficulty was reflected in the fact that in a number of rings made on this date, small bands of phloem remained connecting the upper and lower parts of the branch. By April 9th ringing was easier, but the cambium cells were not easily separated from the woody cylinder. Rings made before April 9th will subsequently be referred to as " rings made before bud break," and because they give similar responses will be considered together.

On March 17th a slow gradual disappearance of starch began from the tissues under and above the ring, this disappearance becoming very rapid about May 5th so that by May 20th these tissues were entirely depleted of starch content. Up to this latter date there was very little development of the

characteristic viscous substance described in the previous paper. By the 5th of June there was a considerable development of this substance in the medullary ray cells immediately under the exposed surface of the woody cylinder, although comparatively little of it had escaped into the vessels. Other considerations showed that it was about June 5th that new xylem was first added in the two-year old branches, and the tree as a whole attained its full leaf stage.

In those rings made in June, July, and August, gum development was observed in the medullary ray cells immediately under the exposed part of the woody cylinder in about ten days, and within a month the vessels to a depth of approximately 0.2 mm. beyond the deepest point of penetration by the knife edge were completely plugged with this wound gum. In rings made during the above months the development of wound gum and the plugging of the vessels rarely proceeded any further than that just described. It was very noticeable that the gum development was most pronounced below the knife incision at the lower edge of the ring. This suggests that substances moving up the xylem may in some way be causally related to its production.

The effect of covering the rings with adhesive tape upon the amount of wound gum developed is most marked, there being far less under the covered than under the uncovered rings. It was also observed that the wound gum which developed under the covered rings was more globular and less viscous than under the uncovered ones, and remained in this state much longer. In the uncovered rings the wound gum rapidly escaped into the vessels, whereas in the covered ones it remained more restricted to the medullary ray cells. It also stained less rapidly with Cotton Red, and gave less intense lignin reactions than that developed under uncovered rings.

Ringing before bud break, at least when it was done on the two-year old branches, often proved fatal to the parts above the ring. Nothing unusual was observed until the middle of August, when almost the whole of the branches ringed before bud break had become so weak and brittle at the point of ringing that they had broken off. Sections of these branches at the point of ringing revealed the fact that death, with a consequent copious gum formation, had progressed at least half way and in some cases the whole way across the stem. By September only two branches ringed in February remained, the others having all broken off. It should be recorded that throughout the long dry period of 1925 the leaves of these branches were never observed to wilt.

Longitudinal sections through a considerable number of ringed areas were examined, and measurements taken of the knife edge incision into the xylem cylinder. As already indicated the rings were made with reasonable care, but quite within the scale of practical operation, so that the figures given may be regarded as the average that is likely to occur in practice. The mean depth of penetration was 0.3 mm., varying between the extremes of 0.2 and 0.5 mm.

It should be pointed out that the vessels are always rendered functionless further than the deepest point of knife edge penetration by being plugged up with wound gum. In any case, where ringing is carried out in June, July or August, rarely, if ever, more than 30 per cent. of the *previous* year's wood growth is likely to be rendered functionless.

Thus, the amount of wound gum developed is not excessive except where ringing is carried out before bud break. The rings made after August developed very little indeed. The time sequence is therefore very much the same as that indicated in the previous paper, although the quantity of the viscous substances involved is much less than would be expected from that study of the severed branch ends.

IV. GENERAL OBSERVATIONS.

(*a*) *Upon the relation of time of ringing to rate of callus formation.*

In no case of uncovered rings was there any callus growth from the edges of the rings before about June 5th, 1925. On this date a small amount was found developing from the upper edges of the uncovered rings made in May, and from the upper edges of the covered rings made in April and May. Experiments in progress in the Spring of 1926 indicate that the failure to obtain callus earlier in 1925 was due to the fact that it was only at the end of May that rings were covered. Callus was developing from the upper edges of covered rings as early as May 6th in 1926. As previously noted, it was about June 5th, 1925, that the trees as a whole attained their full leaf stage. It will be shown in a future communication that the period end of May to end of first week in June, is critical from another and more important point of view, namely that in it starch begins to accumulate in the xylem parenchyma after its preliminary depletion in Spring.

The callus that developed at the upper edges of the uncovered rings was a rough brown, warty, excrescent type of growth, tending to proliferate into a collar of tissue at the upper limit of ring. It grew slowly downwards over the exposed woody cylinder and contrasted sharply with the callus produced under a covered ring, where it was light brown in colour and grew rapidly downwards over the exposed xylem. In fourteen days after the 5th of June the exposed xylem of the covered rings was completely covered with callus, whereas in the majority of the uncovered rings it was not completely covered by October, 1925. In this work there was rarely observed any callus growth from the lower edges of uncovered rings.

Rings made on June 16th rapidly developed callus, particularly those covered over which showed appreciable amounts in six days. The uncovered ones on the other hand were at least fourteen days before they showed any callus. The interesting point in connection with rings made on June 16th is the fact that those covered over developed callus from both upper and lower edges although in very unequal amounts, that from the lower edge being relatively

very small. The middle of June stands out again as an important period in these considerations, because it was found that the re-establishment of organic continuity in the tissues external to the xylem was much more certain when there was callus from both edges of the rings. In the case of uncovered rings made any time during the period February to August inclusive, and of covered rings made before June, it was found that although callus had completely covered the xylem yet there was no actual organic fusion of the tissues external to it. (See Text Figure 1, Plate I.)*

Rings made in July and August developed callus very rapidly, particularly those covered over. In these latter, the amount was almost equal from both edges, and almost invariably fused. In the September made rings callus was much slower in forming, the uncovered rings scarcely producing any at all. The October made rings failed to form any on those left uncovered, and it was very small in amount from the edges of the covered ones. (See Text Fig 1, Plate I.)

(*b*) *Upon the effect of covering rings over with adhesive tape.*

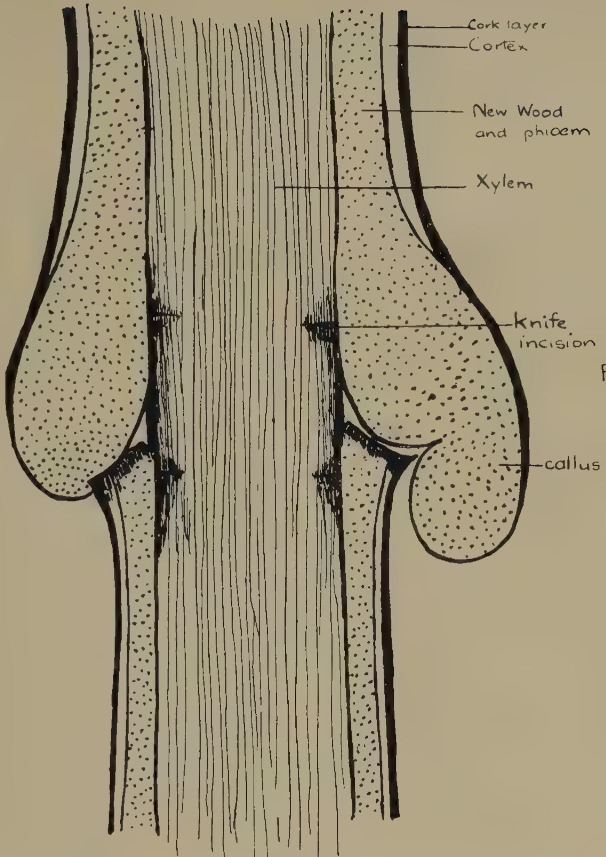
It was shown earlier that covering over the rings with adhesive tape greatly accelerated the rate of callus formation as compared with rings not so covered. It was also indicated that there was no callus formation from the edges of uncovered rings before the early part of June.

The type of response also differs somewhat in the two cases. Considering first the covered rings it was found that the first callus produced was almost entirely due to the proliferation of the phloem. Within ten to fourteen days a phellogen layer developed over the surface of the proliferated tissue. This superficial meristem grew very rapidly and was responsible for the larger part of the ultimate callus. The cambium proper proliferated but slowly, appearing in some cases to become continuous with the superficial phellogen layer just described. The tissue resulting from the joint activity of the phloem and the phellogen grew down into the space left by the removal of the ring of cortex and phloem, and as already indicated in some cases it grew over the lower edge of the ring. Except where callus was growing from the lower edge there was rarely an organic unity re-established in the parts external to the xylem, at least during the current year. The tissue that developed under the covered rings was made up of relatively large irregular shaped thick walled parenchyma cells, comparatively soft and white, with very little starch content. On removing the adhesive tape the surface of the tissue rapidly turned a dark brown colour.

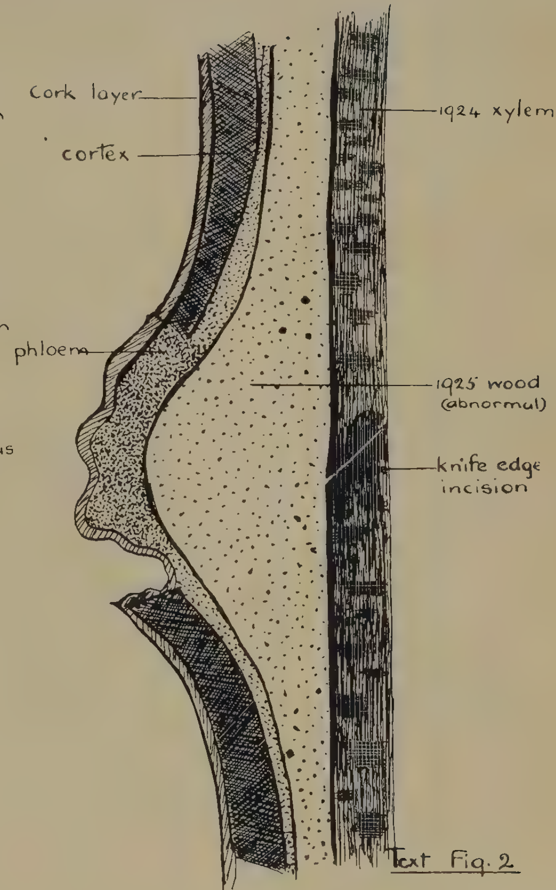
The callus that developed from the upper edge of an uncovered ring was much smaller in amount than that from the covered ones. The proliferation in this

* Owing to certain exigencies of reproduction, it has become necessary to present these "Text Figures" as a Plate.—Ed.

PLATE I.



Text Fig 1.



Text Fig. 2

case tended to be in a radial direction as contrasted with a longitudinal one in the covered rings. The restricted space resulting from the adhesive tape probably goes a long way towards explaining this difference. In the uncovered rings, the cambium proper played a much greater part in the production of the callus. The rolled, knotty, overlapping swellings which occur at the upper edge of an uncovered ring are due to the activities of the superficial meristematic layer being superimposed upon the proliferation of the cambium and phloem in a radial direction.

Another marked effect of covering over rings made after the end of June, was the proliferation of the exposed ends of the medullary rays. This development also took place in the September and October made rings, despite the fact that these latter produced little, if any, callus. It seems probable that the differences in response caused by covering over the rings is related to the relative amounts of drying out in the two cases. Covering over the rings has an effect upon the rate, and in some cases upon the type of wood growth increment that takes place above and below the ring.

TABLE I.—*Showing effects upon the growth of wood phloem and cortex of ringing two-year old branches. Measurements in mms.*

No.	Date of Ringing.	Date of Sectioning.	Remarks.	1925 Xylem.		Phloem.		Cortex.	
				Above	Below	Above	Below	Above	Below
1	17.2.25	9.4.25	Ring not Covered ..	None	None	0.20	0.19	0.41	0.46
2	,,	5.5.25	,, ,, ..	None	None	0.21	0.21	0.47	0.45
3	,,	9.7.25	,, ,, ..	0.38	0.12	0.33	0.18	0.49	0.51
4	12.5.25	26.5.25	Ring Covered ..	None	None	0.23	0.21	0.46	0.47
5	,,	5.6.25	,, ,, ..	0.18	None	0.25	0.18	0.48	0.46
6	,,	23.6.25	,, ,, ..	0.42	None	0.45	0.23	0.50	0.35
7	,,	9.7.25	Ring Not Covered ..	0.66	None	0.42	0.20	0.50	0.42
8	,,	,,	Knife Edge Ring ..	0.92	0.33	0.31	0.21	0.51	0.50
9	,,	27.7.25	,, ,, ..	1.25	0.50	0.33	0.20	0.40	0.43
10	,,	20.8.25	Ring Covered ..	1.17	0.42	0.57	0.33	0.49	0.46
11	,,	,,	Ring not Covered	0.55	0.50	0.56	0.30	0.39	0.41
12	,,	30.9.25	Ring Covered ..	1.60	1.00	0.42	0.20	0.45	0.39
13	5.6.25	23.6.25	,, ,, ..	1.03	0.47	0.37	0.27	0.32	0.50
14	,,	,,	Ring not Covered ..	0.42	0.13	0.32	0.30	0.46	0.47
15	18.6.25	27.7.25	Ring Covered ..	0.47	0.18	0.33	0.27	0.61	0.60
16	,,	,,	Ring not Covered	0.30	0.13	0.30	0.21	0.45	0.33
17	13.7.25	,,	Ring Covered ..	0.80	0.72	0.33	0.29	0.48	0.45
18	,,	,,	Ring not Covered	0.55	0.40	0.30	0.23	0.45	0.44

V. EFFECTS OF RINGING UPON STEM ANATOMY.

(*a*) *Upon amount of growth.*

An analysis of Table I. which gives a summary of some measurements of the effects of ringing upon the amount of wood growth increment, reveals the following points of interest. First, the greater amount of wood growth

produced above a ring as compared with that below it ; secondly, that when ringing is done before June, radial growth begins above a ring at least three weeks earlier than it does below it. In all cases where ringing was done before July there was approximately double the amount of wood growth above the ring as compared with that below it. Ringing after the end of June has very little, if any, effect upon the relative amounts of radial growth produced. Covering up the rings tends always to increase these differences in amount owing to an increase in the actual amount produced above the ring.

The effect of ringing upon the cortex and phloem development is interesting. Reference again to Table I. indicates that there is invariably a greater amount of phloem developed above the ring than below it. The differences in amount are not great, but are consistent. There is of course always the additional difficulty that the new phloem growth is superimposed upon that developed in the previous seasons. It might therefore be objected that the extra amount of phloem recorded was apparent and not real, that is, it was due to the enlargement and swelling of the previously existent phloem. Careful observation and measurement, however, does not support this objection, but establishes the fact that the larger amount of phloem is due to an increased production of new tissue as the result of cambial activity (see Figs. 1-6). The cortical tissues, on the other hand, show no significant differences in amount either above or below the ring.

(*b*) *Upon Stem Anatomy.*

Considering first the rings made before bud break, it was previously indicated that in the two-year old branches radial growth began above the rings at the beginning of June, whereas it was at least a fortnight later before it began below them. Figs. 1 and 2, Plate II, are from micro-photographs taken respectively from above and below a ring made on February 17th and gathered for examination on July 9th (Number 3, Table I.). The sections were taken at 2.5 cms. from the limits of the ring. The section from above the ring (Fig. 1) shows the production of a considerable amount of normal spring wood. The last few cells cut off by the cambium are, however, abnormal in type. They consist of large elongated thick walled cells which are neither true vessels nor tracheids. The cambium is very well developed and there has been a considerable addition of new phloem. Fig 2, from a section taken below the ring shows the formation of a very small amount of spring wood which is followed by the production of typical autumn wood. The cambium is poorly developed, and the new phloem that has been added has relatively thick walls. The previous season's phloem has become slightly lignified. The relative amounts of new xylem produced above and below the ring are easily compared in these two figures which are comparable in every way. In any interpretation of the above facts it must be

remembered that ringing was done before there was any recognisable disappearance of stored food material from the parenchyma cells of the xylem.

Considering next the rings made on the 12th of May, Figs. 3 and 4, Plate II, are respectively from above and below a ring made on that date and gathered for examination on June 20th. The sections in this case were taken at 1.0 cms. from the limits of the ring. Fig. 3, from above the ring, shows a considerable growth of an abnormal type of tissue. It is made up almost entirely of large elongated parenchyma cells. The cambium is conspicuous, being many cells deep, the individual cells being comparatively large, translucent in appearance, turgid, and full of dense protoplasmic content. Further above the ring (5.0 cms.) the new wood growth was almost normal in type but smaller in amount. Fig. 4 is of the section from below the ring. In this case the cambium has not yet begun to grow; in fact it appears somewhat degenerate, the cells being dark coloured and wrinkled. There was still no cambial activity at 3.0 cms. below this ring.

The sections shown in Figs. 5 and 6, Plate III, are from a branch ringed on the same date as that of Figs. 3 and 4 (May 12th), but which was not gathered for examination until August 20th (Number 10, Table I.). The sections were taken at 3.0 cms. from the limits of the ring. The types of wood growth produced above and below the ring show considerable differences. The section from above the ring (Fig. 5) indicates several zones of abnormal cells. First there is the production of a considerable amount of normal spring wood, which is followed by a zone of large elongated parenchyma cells similar to those described as occurring in the section shown in Fig. 1. In fact, up to this point, the section is very much like that shown in Fig. 1. Beyond this zone of large elongated parenchyma cells is a region of even more elongated cells with oblique ends, in shape resembling tracheids when seen in longitudinal section, but almost square in outline when seen in transverse section. These cells have relatively thick walls and are invariably packed with starch. Following upon this band of " square " cells is a zone of more rounded cells with even thicker walls which are heavily impregnated with lignin and fatty substances, particularly the latter. Below the ring (Fig. 6) the wood is almost normal in type, although the number of vessels formed is much less than usual, the relative amount of tracheids to vessels being correspondingly increased. There is, however, below the ring a very interesting feature which is shown in Fig. 10, Plate IV. It is a double row of regular, oblong, barrel shaped, square ended cells. They have relatively thick walls, large lumen, and have no protoplasmic contents but only large crystals. They lie between the autumn wood of 1924 and the wood produced in 1925. It will be remembered that ringing on May 12th considerably retarded the initiation of cambial activity below the ring, and these are the first cells differentiated by this cambium when it began its activity. The amount

of phloem developed above and below the ring has already been compared, The individual phloem elements are larger above the ring than below it. Similarly the cambium is much more conspicuous above the ring. As seen in transverse section it is several cells deeper than the cambium below the ring, and the individual cells are longer tangentially than are those below the ring. The facts just described have no exception in rings made on May 12th so that they cannot but have caused erable significance.

The effects of ringing in June now·remain to be described. Figs. 7 and 8, Plate III, are respectively from above and below a ring made on June 5th and gathered for examination on July 9th. The abnormal type of wood growth is in this case found to occur *below* the ring. Fig. 7 indicates that above the ring the wood growth is almost normal both in type and amount. There is one very interesting point to be observed, namely the number of globules present in the medullary ray cells. These are globules of the viscous substance allied to wound gum, described in the previous paper. They are also shown in surface view in Fig. 11. Fig. 8, taken from below this ring shows the several zones of abnormal wood cells produced. The section is in its main details similar to that shown in Fig. 5 except that there is no zone of large open cells.

The actual response therefore, as reflected in the structural development of the wood growth increment, is conditioned largely by the time of ringing relative to periods in the seasonal growth activity. In 1925, at Long Ashton, the results of ringing two-year old branches allows of the following generalisations. Ringing before bud break results in a reduced amount of wood growth below a ring as compared with above it. Ringing in May or before results in an abnormal type of wood growth *above*, but has a much smaller effect upon the wood growth below the ring. Ringing in June after radial growth has begun, results in abnormal types of wood cells being produced *below* the ring. The factors acting upon the cambium in such a way as to engender the formation of these peculiar types of cells, in one case above and in the other below the ring, are not yet clear.

VI. The Effect of Knife Edge Ringing.

The effects of knife edge ringing as compared with those where a complete ring of cortex and phloem is removed, must now be described. From Table I. it can be observed that the branch which was knife edge ringed (numbers 8 and 9) on May 12th, had, by July 9th, made at least a third as much more radial growth above the ring as the branch that was completely ringed on the same date, even though the latter had been covered over with adhesive tape. Also, the knife edge ringed branch had made radial growth *below* the ring, whereas the completely ringed branch had not.

The explanation of these facts is probably to be found in the observation that within ten days after making a knife edge ring—provided it is made during

the months June to August inclusive—the tissues external to the woody cylinder particularly the phloem, are again in organic continuity (see Text Fig. 1, Plate I.). It is probable that after this fusion has taken place, the normal functions are again possible, though doubtless at a reduced rate. The connecting tissue that develops at the point of knife edge ringing is made up of comparatively large, elongated, parenchyma cells. Sieve tubes as such have not been observed to occur in it. On the xylem side of the cambial layer at the point of ringing, an abnormal type of xylem tissue is cut off. This tissue is made up of relatively few vessels, a considerable amount of enlarged tracheid elements along with a much larger proportion of wood parenchyma and medullary ray cells than occurs normally. Thus, the major effects of knife edge ringing can at best be of a transient nature only, owing to the comparatively rapid healing and fusion of the severed tissues with its consequent re-establishment of the normal channels of translocation. All these points are diagrammatically illustrated in Text Figure 2, Plate I.

VII. Effect of Double Ringing upon Amount of Wood Growth.

Figure 9, Plate IV, is from a photograph of a branch double ringed on the 12th of May, and photographed on 24th of September, 1925. The general results of double ringing are too well known to need elaboration of this point, but the following points are worth noting in this particular case. The first is the large amount of callus growth from the upper edge of the higher ring, and the negligible amount from the upper edge of the lower one, along with the absence of callus from the lower edge of *either* ring. Secondly, there is the vigorous shoot growth from the two buds next below the lower ring, whereas the buds *between* the rings have not grown out into extension shoots. These four buds were similar to each other when the rings were made, hence the qualitative differences in growth response made by them cannot be ignored. The last point of general interest is the fact that many of the buds *above the upper* ring have plumped up into fruit buds, and by this date defoliated, whereas the leaves of the two buds between the rings and those of the vigorous extension shoots below the lower ring were still green and functional. Leaf fall took place on the parts above the ring at least a fortnight before this photograph was taken. These facts, along with others giving the amount of new wood growth above, below, and between the rings must be added to the body of experimental evidence that is being accumulated upon the general problem of the possible functions of the xylem and phloem in the conduction of organic substances about the plant.

Table II. gives the measurement of the amount of new tissue growth above, between, and below the rings (see Fig. 9). The position of these sections relative to the rings is as follows :—(a) at a point 1.5 cms. above the upper limit of the upper ring. The first leafy bud was at least 1.0 cms. above the position where section (a) was taken. Section (b) was taken midway between the two rings

TABLE II.

Tissue.	(a) Above.	(b) Between.	(c) Below.
New Wood 1925	cms. 0.60	cms. 0.21	cms. 0.66
Phloem	0.39	0.25	0.33
Cortex	0.43	0.42	0.45

i.e., 2.5 cms. from either, and between the two buds already mentioned ; (c) was taken at 1.5 cms. below the lower ring, i.e., between the points of origin of the two extension growths. Reference to Fig. 9 will make this description clear. It is clear from Table II. that the amount of new wood growth produced between the rings is much smaller than that produced above or below them. That recorded for sections (a) and (c) is almost equal, due no doubt to the relative positions at which they were taken. The type of tissue produced above the ring is similar to that illustrated in Fig. 5 ; that between the rings (b) to that of Fig. 2 ; that below the ring (c) was normal except that there was very little spring wood.

The starch distribution in these sections is interesting. Above the ring the cortex, phloem, medullary ray and wood parenchyma cells were packed with starch. Between the rings it was present in the medullary ray and wood parenchyma cells to a limited extent, but was almost absent from the cortex and phloem. Below the ring, there was an abundance of starch in the same tissues as above it although the amount was less. It is unfortunate that no other double rings were made, and while it is not permissible to base too much upon this single case, the evidence it affords cannot but strengthen that presented in the previous sections.

VIII. The Effect of Time of Ringing upon Time of Bud Break.

In the Spring of 1926 the following observations were made upon the branches ringed during the previous Summer. Ringing has a marked effect upon bud break depending upon the date of ringing. The branches ringed before the end of the first week in June had developed a large number of flower buds above the rings. These were all fully expanded by April 15th, 1926, which was at least a fortnight before those on the normal parts of the trees. These trees as a whole did not have a large show of blossom in Spring, 1926, so that the branches ringed before June 7th were quite conspicuous. It was thought that there might be a reverse effect upon the vegetative buds, but over the limited number of trees under observation there was no noticeable difference between time of vegetative bud break on ringed and normal branches. Ringing after the end of July, however, has the reverse effect of ringing before June. Not only had such rings failed to induce flower bud formation above them, but their

vegetative buds were at least ten to fourteen days later in breaking than those on normal branches. Further observations upon these differences are both desirable and necessary before any discussion can be attempted, although their physiological significance is fully realised.

IX. Discussion.

A complete discussion of all the points raised by this paper is not here intended, because further work is still in hand upon the relationship of the storage and depletion of the starch reserves of the xylem parenchyma to the practice of ringing. It should be pointed out that the present approach to the problem of ringing is entirely different from that of Barker and Lees (1). These workers were more interested in the practical use of ringing as a method of increasing productiveness in fruit trees, whereas in the present work it was more detailed knowledge of a particular aspect of the general physiological problem that was sought. Certain points of practical importance emerge, and awaiting further experimental knowledge these are here tentatively discussed. For a brief review of the more general results of ringing the paper by Barker and Lees may be consulted.

When ringing a shoot, one is likely to damage and so render functionless the woody cylinder to a depth of about 0.3 mms. by cutting into it with the knife edge. The tissue immediately internal to this incision is also rendered functionless for a further 0.1-0.3 mms. by the blocking up of the vessels and tracheids with the viscous substance provisionally called wound gum. At most then, when ringing is done in the period late May to mid-August, one is not likely to damage more than 30-50 per cent. of the previous year's wood growth. Thus, when ringing is done on the larger limbs the total amount of xylem rendered functionless will be almost negligible. The objection of Dixon (4) to the use of the ringing method as a means of determining the function of the xylem and phloem in translocation, is based upon the assumption that it is only the outer layer of xylem vessels which is functional in translocation. This assumption does not appear to be critically established. In any case, it is clear that Dixon's theory of translocation in the outer parts of the xylem is difficult to reconcile with the evidence of Curtis (2) Gardner (5) and that here recorded. Although Gardner records as a result of ringing, a lowering of the conducting capacity of the stem by 45 per cent. as a maximum figure, and the histological evidence presented in this paper indicates that not more than 50 per cent. of the previous year's wood growth is likely to be rendered functionless, yet the leaves above such rings are rarely if ever observed to wilt. Some of the branches used in this work carried a very large leaf area above the ring. Thus, the remaining xylem *is* adequate for water conduction to a relatively large leaf area. It is here suggested that we must look further than the mere severing of one or other of the possible channels of translocation in order to understand and explain

the several effects of ringing, and that a discussion based only upon the removal or deposition of starch is likely to be misleading. There is a strong case for regarding the continuity of the tissues external to the woody cylinder (particularly the cambium and phloem) as being a necessary condition for rendering the stored starch available for use at a distance in Spring. The primary question to discuss is not the particular channel of translocation, but the factors that so affect the cell metabolism as to set in motion the conversion of starch into more soluble forms of carbohydrate.

The different effects produced by ringing at different times of the year are instructive. The more obvious growth responses to ringing are recorded in the work of Barker and Lees already referred to. The disastrous result of ringing two-year old branches in February is outstanding. Whether ringing at this time would have a similar effect upon large limbs is not yet known, although the point is obviously important. Mr. Lees informs me that in the conduction of the ringing experiments already mentioned, he distinctly remembers several branches particularly in plum trees, being killed by ringing very early in the season. The fact that ringing after the middle of June results in callus growth from both edges of the ring, whereas ringing before then results in callus from the upper edges only, is of practical importance in deciding when to ring fruit trees. It is now known that the differentiation of fruit buds in apple trees takes place normally during late June and early July. It is clear, therefore, from all the previous considerations that the best time for ringing would normally be about the end of the first week in June. This would give the maximum desired result as regards fruit bud formation, and would at the same time allow a maximum opportunity for the wound to heal over. In view of the increasing evidence (9) that the conditions necessary for fruit bud formation and the setting of the flowers are by no means similar, it seems very desirable that the rings should heal over and re-establish organic connection in the same year as they are made. The healing over is the important point, because it does not always follow that when a ring is covered over with callus the tissues external to the xylem are in organic continuity. It is shown that the re-establishment of this continuity will be best accomplished by making comparatively narrow rings at about the middle of June. It is, therefore, suggested that normally the end of the first week in June will be the best period for ringing fruit trees in order to ensure fruit bud formation and to safeguard the life of the parts above the ring.

The seeming erratic results obtained by knife edge ringing are partly explained by the work here presented. It was found that during the period June to August the tissues external to the woody cylinder were in organic continuity again within eight to fourteen days after ringing. From a consideration of the present and previous work it is highly probable that knife edge rings made in May will not heal up so quickly. This is because the cambium at that time is not actively

growing and dividing, and the cells bordering the wound are much more likely to dry out before new callus formation begins. The comparative ineffectiveness of knife edge ringing at certain times of the year is no doubt explained by the early re-establishment of the organic continuity of the tissues external to the xylem. Where fruit trees are not too vigorous, yet are so vigorous as to be unproductive, the employment of knife edge ringing in May is suggested as a temporary measure of increasing bearing, pending radical cultural treatment.

Considering next the type of wood cell, we find that ringing has a pronounced effect upon the anatomy of the xylem. It was mentioned earlier that the early part of June is a critical period because in it the trees attain to their full leaf stage, and reserve products, particularly starch, are again stored in the xylem parenchyma. Further work upon this problem is well in hand and will be communicated in a future paper. Ringing *before* the reversal in starch content results in the production *above* the ring of three bands of different types of abnormal cells, whereas ringing *after* the reversal has set in results in the production of abnormal cells *below* the ring. Ringing before the reversal results in the following sequence of tissue development. First, a small amount of normal Spring wood; this is followed by a zone of large open elongated parenchyma cells, which is followed by a band of " square " starch packed cells, which is in its turn followed by the " rounded " thick walled cells. (See Fig. 6.) Ringing after the reversal in starch content results in the production below the ring of the two latter bands only. This effect of ringing upon anatomy is interesting in view of the work of Harper (6) and Harvey (7) who record the production of almost similar types of cells as a result of defoliation. Harper attributes this abnormality to lack of food, particularly carbohydrates. This suggestion, however, is inadequate for all the results here recorded. Wormall (13) has recently shown that the sap of vines contains numerous enzymes and organic acids. It is probable that in both ringing and defoliation, while the question of food is undoubtedly involved, we shall have to look into the more deeply seated physiological changes, particularly those that react upon the growing meristem cells of the cambium.

The recorded work upon ringing, even where quantitative data has been obtained, does not contain an easy solution to the problems involved in the production of these abnormal types of cells. In view of the production of almost similar types of cells as the result of both defoliation and ringing, it is obvious that we must look for some common factor that could be regarded as causal. The evidence of Kraybill (10) is that ringing lowers the moisture and total nitrogen above a ring, but increases the reducing sugars. Similarly, a bearing tree is also lower in moisture and total nitrogen as compared with a non-bearing. Harvey and Murneek (8) on the other hand show that defoliation results in an increased water content as compared with controls. It is therefore

very difficult to relate the peculiar types of wood cell produced to water content. The much discussed carbohydrate-nitrogen ratio does not appear directly causal, for it is shown by Harvey and Murneek (8) Harvey (7) and Kraybill (10) that ringing results in a higher and defoliation in a lower value of this ratio. In fact the only constant resulting from both operations is an increase in the reducing sugars, and probably total sugars. It seems probable that the explanation will be found in a change in the nature and reaction of the fluids moving in the plant tissues, such as Pearsall and Priestley (11) suggest.

X. Summary and Conclusions.

The previous work on wound healing has been extended to cases where a ring of cortex and phloem only is removed, using two-year old branches.

The amount of the viscous substance allied to wound gum is relatively small, and is produced most abundantly in those rings made after the beginnings of starch re-deposition in the xylem parenchyma.

There was no callus produced from the uncovered rings before June 5th, which date is correlated with the beginning of starch re-deposition and the attainment of the full leaf stage in the tree as a whole. Callus develops most rapidly during the latter half of June and the first half of July.

The covering of rings with adhesive tape greatly accelerated the rate of callus formation as compared with rings not so covered. After June 16th the covered rings developed callus from both upper and lower edges, whereas previously it developed only from the upper edge. Uncovered rings did not produce any callus from the lower edge. After mid-June the ends of the medullary rays under the covered rings proliferated to a considerable degree.

Ringing before the end of June resulted in double the amount of radial growth above the ring as below it. There is also a greater amount of phloem produced above the ring, whereas the cortex remains unaffected.

Effects upon stem anatomy vary with the time of ringing. Ringing before the 5th June results in an abnormal type of wood being produced above whereas if done after this date the effect is below the ring.

Knife edge rings rapidly heal over particularly when made in June and July. This probably accounts for the erratic results obtained from this method.

The effect of double ringing is effectively to restrict the amount of radial growth between the rings as compared with that produced above the upper and below the lower rings.

The bearing of this work upon the employment of ringing as a commercial practice is tentatively discussed.

The bearing of the present work upon the problem of translocation is indicated, and a suggestion is put forward as to employing the disappearance of starch from wood parenchyma as a criterion of translocation.

Possible causal factors involved in the formation of the abnormal types of xylem tissue are suggested.

It is also tentatively suggested that provided that ringing is done at a suitable time, which will normally be during the early part of June, and precautions are taken to ensure the re-establishment of the organic continuity of the tissues external to the woody cylinder, the practice is not likely to do damage to the tree. Ringing before the middle of April does not appear advisable.

Some observations upon the effect of ringing at different times upon the time of bud break are recorded.

It will be understood that the times recorded above for the physiological responses of the tree to ringing were obtained under Long Ashton climatic conditions prevailing during the period covered by this work. The individual times stated would probably be subject to variation from year to year, both according to the location and the character of the season.

I wish to acknowledge the receipt of a Ministry of Agriculture Research Scholarship while carrying out this work. My thanks are due to Professor J. H. Priestley, Department of Botany, University, Leeds ; also to Professor Barker, Long Ashton Research Station, for facilities to carry out this work.

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EXPLANATION OF PLATES.

Plate I. See Text.

Plate II.

Figs. 1 and 2 are respectively from sections taken above and below a ring made Feb. 17th and gathered for examination July 9th. Note differences in amount of xylem and phloem in the two cases.

Figs. 3 and 4 are respectively from above and below a covered ring made May 12th and gathered for examination June 20th. Note that cambial growth has not begun below ring (Fig. 4) and the abnormal wood growth above it (Fig. 3).

Plate III.

Figs. 5 and 6 are respectively from above and below a covered ring made May 12th and gathered Aug. 20th. Note the almost normal type of growth below ring (Fig. 6) and the abnormal above it (Fig. 5.)

Figs. 7 and 8 are respectively from above and below a covered ring made June 5th and gathered on July 9th. Note that the abnormal type of cells is produced *below* ring (Fig. 8). Also compare amounts of radial growth in two cases. Also note the presence of the viscous globules of wound gum in medullary ray cells.

Plate IV.

Fig. 9. Photograph taken on Sept. 24th of a branch double ringed on May 12th. Note distribution of callus also the leaves. Rings not covered over.

Fig. 10. Section showing the long barrel shaped cells with crystals, produced by cambium below ring. From same branch as Fig. 4.

Fig. 11. Section showing the viscous globules of wound gum in medullary ray cells, in surface view. Note also protoplasmic connections.

PLATE II.

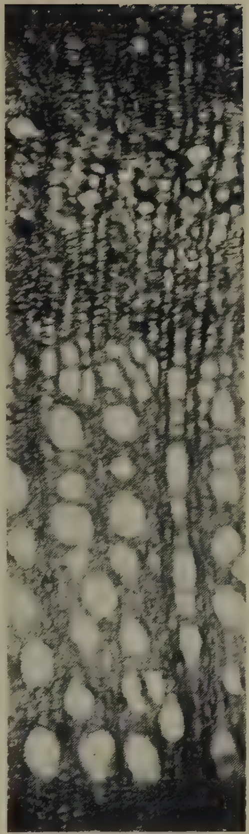

Fig. 1.

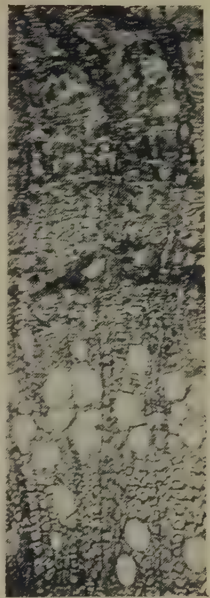

Fig. 2.

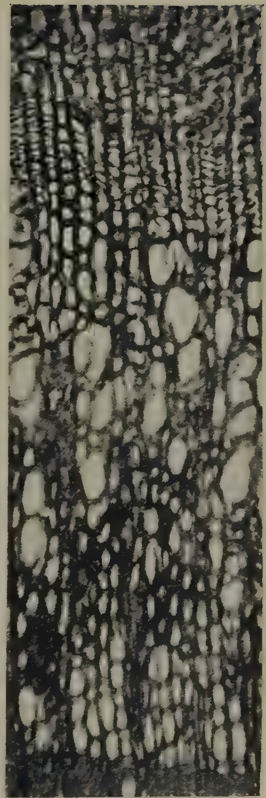

Fig. 3.

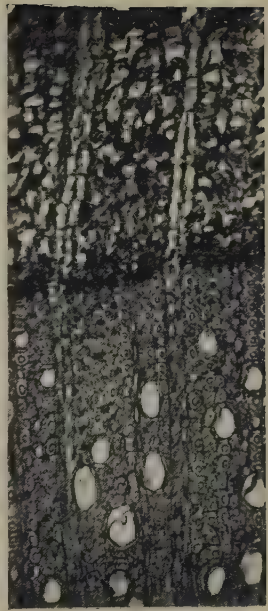

Fig. 4.

PLATE III.

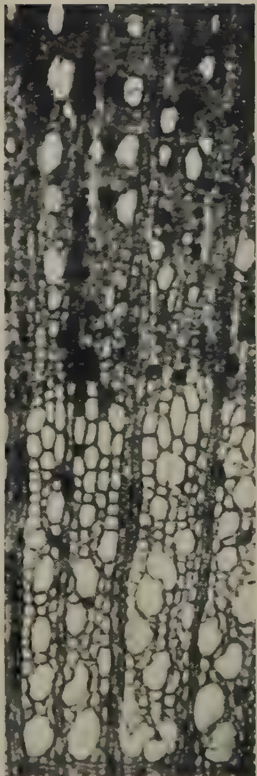

FIG. 5.

FIG. 6.

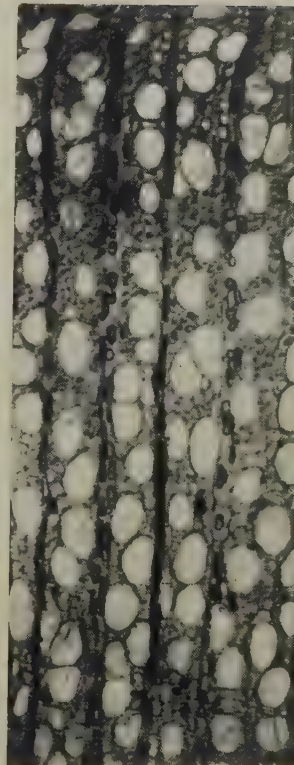

FIG. 7.

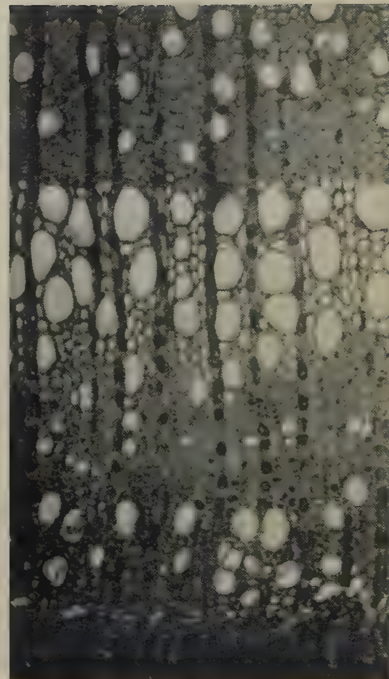

FIG. 8.

PLATE IV.

FIG. 9.

FIG. 10.

FIG. 11.

THE PROPAGATION OF FRUIT TREE STOCKS BY STEM CUTTINGS.

II. TRIALS WITH HARD- AND SOFT-WOOD CUTTINGS.

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THE vegetative propagation of desirable varieties of plants is an everyday procedure of the horticulturist and the advantages of the method do not need to be emphasised here. It is used in commerce for the multiplication of some fruit tree stocks; for example, the so-called "paradise" apple stocks, formerly recognised as having dwarfing characters, are raised from stools or layers. The layering process is also adopted for propagating some varieties of plum stocks such as Brussel, Brompton, Mussel and Common Plum, and some of these are also sometimes grown from root cuttings. In addition natural plum suckers from the orchards are frequently used for propagation. Young plants of the cherry are obtained from the woods and used as stocks, and these in many cases are doubtless vegetative suckers.

However, recent horticultural research has indicated the desirability of applying vegetative methods much more widely than hitherto in the practice of raising fruit tree stocks.

With some varieties, difficulty has been encountered in achieving any measure of success which is of practical value. Some details of the readiness with which varieties may be multiplied by various vegetative means are given by Hatton (4) and by Hatton, Amos and Witt (6), and the subject has also been studied by Auchter (1), Maney (10), Swingle (18) and Zimmerman (20). All these authors have observed the difficulty of propagating some varieties vegetatively. The relative simplicity of propagation from seed constitutes a great attraction from the nurseryman's point of view, but it is now recognised that genetical uniformity of nursery stock is often of major importance.

In such cases it is therefore essential that vegetative methods be employed, and it remains to discover methods which shall be suitable for particular varieties, and also practicable on a commercial scale. Propagation by stem cuttings naturally suggests itself. Usually the material for such propagation is easily obtained, which is not always the case with root cuttings, and the procedure in its simplest form is less involved and less expensive than that

required for layering or stooling. Furthermore, stem cuttings can be planted very close together, a distinct advantage where space is restricted. Such features of the method render it attractive to the propagator, but there are certain conditions to which it must conform if it is to be of economic value.

It may be true, as Bayley Balfour contended (2) that it is possible to reproduce any plant by stem cuttings, if suitable material is chosen and a suitable environment provided. A large majority of the fruit tree stocks and varieties which have been tested at this Station have at one time or another been successfully propagated vegetatively. For practical purposes, however, it is not sufficient, for example, that out of every hundred cuttings planted, an average of ten become established. Ten per cent. of successes do not render a method suitable for economic application in the case of root stocks. It is generally necessary that more than fifty per cent. of the cuttings shall root before the method can be regarded as commercially successful. It may be suggested that if the environment is such that ten per cent. of the individuals of a batch become satisfactorily established, then the conditions must be near the optimum, and a slight alteration of a factor such as temperature or humidity should induce the remaining ninety per cent. to root, since all the individuals are of the same variety. It must be emphasised, however, that the environment is by no means the only factor concerned in the capacity of a stem to produce roots; the physiological condition of the stem plays an important part in determining the behaviour of the stem when planted. The conditions postulated by Bayley Balfour include the choice of "suitable material," showing that he recognised the importance of internal as well as of external conditions, and the traditions pertaining to the practice of propagation also ascribe special virtue to stems in particular stages of growth. For example, with some plants it is said that success is most easily achieved by using actively growing shoots which must be "kept growing." Reference to previously published work also shows that considerable importance is attached to the rôle of internal factors, and the present experiments have provided ample evidence in support of this view. Consequently, since in any large batch of cuttings there must be in practice, individuals in different physiological states, it is not to be expected that similar environment will produce similar results with every one.

A further condition which must be fulfilled by any vegetative method for reproduction of stocks in order to satisfy practical demands is that the material produced shall have sufficient vigour to be suitable for grafting or budding within a reasonable time. It is a distinct disadvantage if a hardwood cutting takes two years to root, or if a rooted plant is produced in one year but takes a further year to develop sufficiently to "mother" a bud or a graft.

Such considerations as these must be kept in view in seeking to discover methods of vegetative propagation suitable for fruit tree stocks.

HARDWOOD CUTTINGS.

The usual method of planting hardwood cuttings has been described elsewhere (7) and this method has been applied to a large number of varieties at this Station in the course of recent years. It may be of value to give a summary of the results obtained in these trials. It has been usual to have fifty cuttings in each batch, although at times smaller numbers have been used, whilst frequently the unit has been 100. In most cases, at least two batches of each variety were planted in each season. Table I. summarizes the results obtained over seven seasons.

TABLE I.

Percentage of Hardwood Cuttings Rooted under a Variety of Conditions, 1919-25.

Variety	Percentage Rooted		
	Minimum	Maximum	Average
APPLES:			
Stock Type I.	0	5	3
Stock Type II.	0	5	3
Stock Type XII.	0	0	0
Bramley's Seedling	0	0	0
Lane's Prince Albert	0	0	0
Worcester Pearmain	0	0	0
PLUMS.			
Pershore	0	58	14
Common Mussel	0	66	20
Victoria	0	6	2
Purple Egg	0	4	1
Brompton	12	78	33
Mariana	14	100	76
Czar	0	0	0
Brussel	only one trial		2
Myrobolan A.	0	3	2
Myrobolan B.	23	80	52
Myrobolan C.	8	50	29
Myrobolan D.	10	10	10
CHERRIES:			
Mazzard. Selection 12	0	0	0
Mazzard. Selection 2	0	0	0
Austera. Selection	0	0	0

In all these trials, the current season's wood has been used, but it is likely that better results would be obtained if older stems were planted. Cases are frequently reported in which old stems of the apple root readily when their bases are embedded in soil, but it is obviously impracticable to utilise such material for general propagation.

It is clear from the table that the ordinary procedure used for propagation by hardwood cuttings cannot be applied to apple varieties with any reasonable prospect of success. Mahaleb and Austera cherries also fail to produce roots

and soon die. Plums on the other hand are more successful, although the difference between varieties is clearly marked.

A further fact which these trials have demonstrated is that there is considerable variation in the success obtained with the same variety at different times. This variation may arise from two causes, first, the variation in the external environment such as climatic and soil conditions, and second, the difference in the physiological state of the plant when the cuttings are taken.

Factors of both classes have been investigated in relation to hardwood cuttings and the results have already been reported (7). The experiments showed that high water content of the soil is a factor which favours the formation of a callus, which protects the wound at the base of the cutting. The protection afforded by the callus maintains the cutting in a condition which enables it to produce roots if and when the environment becomes suitable. The soil conditions most favourable to root development do not appear to include high water content, and it has been suggested that efficient soil aeration is an important factor in the rooting stage. It should be observed, however, that Zimmerman (20) has reported that willow cuttings, which normally root easily, are apparently unaffected by an atmosphere consisting of 12 per cent. CO_2, 25 per cent. oxygen, and nitrogen. This evidence indicates that willow, at least, does not require very thorough soil aeration in order to produce roots. This plant, however, is known to be abnormal in respect of the reaction of its roots to the composition of the soil atmosphere. Livingstone and Free (9) found that the root development of normal established willow plants was not inhibited when the soil air contained no oxygen. It is therefore not surprising to find that root production from willow cuttings is unaffected by high concentrations of CO_2 in the soil. Direct evidence concerning the response of fruit tree cuttings to different concentrations of CO_2 is still lacking.

The relation of root production in hardwood cuttings to certain other internal and external factors has already been discussed in the paper referred to (7).

Softwood Cuttings.

Although propagation by hardwood cuttings is a method which, if successful, is eminently suitable for raising stocks on a commercial scale, it is not certain that the softwood cutting method is similarly economically practicable; for the latter method, greenhouse accommodation is necessary and the plants require more attention than hardwood cuttings. Thus, even though a similar area will accommodate a much larger number of softwood than hardwood cuttings in a season owing to the shorter time required for establishment, there is a considerable difference in the expense involved in the two methods. It is for the nurseryman to decide whether the results obtained with softwood cuttings compensate for the

time and trouble which they involve, but it probably depends upon the variety concerned. If a desirable stock, which is not easily multiplied by other methods, can be successfully raised from softwood cuttings, it is probable that even this method could be used with economic advantage.

It was impossible to conduct trials with softwood cuttings on the same scale as those with hardwood cuttings, chiefly on account of the limitations of greenhouse space. On the other hand, it is possible to exercise some control over the environment in a greenhouse, and consequently there is less variation in the behaviour of individual batches of cuttings than in cuttings planted in the open.

As in the case of hardwood cuttings, trials were first made to determine the response of different varieties. Cuttings were obtained from various sources, including layers and stools, budded plants, fruiting trees and potted plants, as soon as these had made sufficient growth, and were planted in closed frames in the propagating house. The media used included sand, coconut fibre and soil, and various combinations of these. The cuttings were planted at various dates, and were lifted at intervals which were dictated by their appearance.

The temperature of the media could not, of course, be under complete control, but the range which was aimed at was 65°-75° F., with an air temperature inside the frames about 5° F. lower. Humidity was as high as possible immediately after planting, but was lower in the later stages, and the cuttings were exposed to full daylight as far as was compatible with the maintenance of temperature and humidity requirements. The medium was kept thoroughly moist, but waterlogging was avoided, especially with the more impervious substrates.

The variation in the results with different varieties was still considerable, and Table II. gives figures for a selection of the varieties used.

The number of cuttings in each batch was determined by availability of space and material, and was generally between 60 and 150. In a few cases the number was as low as 25 whilst over 200 were included in some cases.

A comparison of Tables I. and II. reveals some marked differences in the response of the plants to the two methods of treatment. Apple Type XII., for example, has occasionally rooted as hardwood cuttings if left in the beds for two years, but in 1924, 70 per cent. of a batch of softwood cuttings of this variety became established. More remarkable is the case of the Cherries, some of which root only with difficulty or not at all as stools and layers. When planted as hardwood cuttings these rot very quickly, and of most varieties tested not one cutting as yet has been induced to root. As softwood cuttings, however, all varieties tried except F. 3/4 have at some time rooted to a satisfactory extent. When softwood cuttings of plum varieties fail to root, they usually rot within a week or two. Apple cuttings may remain alive a little longer, but it is very unusual to find any large mortality among softwood cuttings of the cherries even after several

TABLE II.

Rooting of Softwood Cuttings under a variety of Conditions.

Variety	Per cent. Rooted		
	1924	1925	1926
APPLES.			
Type IX.	0	0	—
Type XII.	70, 12	—	—
PLUMS.			
Brompton	26, 5	54	10, 57
Common Mussel	9	85, 45	87
Pershore	4	0	37
Damas C.	—	—	69
CHERRIES.			
Mahaleb			
Selection F 6/1	92	24	42
Selection F 7/1	63	4	—
Selection F 8/1	100	19	—
Austera.			
Selection F 4/1	77	80	92
Selection F 3/4	3	0	—

months in the frame. Some varieties are slow to root, but in complete contrast to their behaviour as hardwood cuttings they invariably callus well and remain alive even if roots do not develop. The record of a batch of cherry F.3/4 is worth quoting in this connection.

July 8th, 1924	.. ..	69 cuttings planted.
August 28th, 1924 ..	..	1 rooted, 9 dead, 59 alive.
October 8th, 1924 ..	..	2 rooted, 9 dead, 58 alive.
November 12th, 1924	..	2 rooted, 9 dead, 58 alive.

Among the plums, Common Mussel, with an average of 20 per cent. individuals rooted from hardwood cuttings, may yield 80-90 per cent. established plants from softwood cuttings. There is no doubt that in general, propagation by softwood cuttings is much more successful, judged by percentage of plants rooting, than the use of hardwood cuttings.

Table II. shows that there is considerable variation from year to year in the performance of the same variety. It has already been stated that not only the external conditions, but also the type of cutting has been deliberately varied in this series, and the irregularity of the results is to a large extent due to this variation. It will be convenient to discuss these variants separately, although the results from one batch of cuttings may appear in more than one connection.

THE SOURCE OF THE CUTTING.

There is no doubt that the source of the cutting is of prime importance in softwood propagation. It needs no more than casual observation to detect

differences between current season's shoots on a young tree which has been heavily pruned and those on an old unpruned tree or a tree in a pot. In fact the new growth of the plant accurately reflects the treatment imposed upon it. Furthermore, several different types of shoot may be found at the same time on any one plant. In June the tips of the leading shoots are still in active growth, have a high water content and are not lignified to any great extent. There are also lateral shoots in active growth, which are similar to the leading shoots, but usually less sappy. Some lateral shoots in addition may have ceased active growth and become "woody." Very little is known regarding the nature and quantity of the storage products available in these different shoots in the growing season, but it is reasonable to suppose that the differences in the degree of lignification and in the extent of the growing period are indications of differences in the quantity and quality of the food materials within the shoot. A considerable mass of evidence is available concerning the influence which the chemical composition of a cutting may have upon its rooting capacity (7, 13, 14, 15, 16, 17), and it is therefore evident that some enquiry is necessary into the relative suitability for propagation purposes of different types of cutting, containing presumably different types of reserve materials.

The most easily available sources for cuttings have proved to be the nursery stool beds and layers and stool shoots which have been planted out for budding and grafting, and accordingly trials have been made with batches of cuttings taken from such plants and representing the following types of growth :

A. Leader tips in active growth.
B. Laterals in active growth.
C. Laterals with terminal bud formed.

Table III. shows the results which were obtained with Brompton and Common Mussel plum. The cuttings of any one variety were all planted on the same date and under the same conditions.

TABLE III.

Relation between the Type of Cutting and the Number of Cuttings Rooted.

Variety	Percentage of Cuttings Rooted		
	Type A.	Type B.	Type C.
Brompton	17	33	54
Common Mussel	3	5	17

This table shows the striking superiority of the "half-lignified" type of cutting over the actively growing shoots. In view of the results which have been obtained with other plants this might be expected. It has been found

(13, 14, 15, 17) that tomato cuttings which have a high carbohydrate content produce roots more readily than cuttings which are less rich in these substances. Although no analyses were made in the present experiments, it is reasonable to suppose that shoots which have ceased active growth are likely, on account of the activity of their mature leaves, to have a higher carbohydrate content than actively growing shoots from layers or stools which have been heavily pruned.

Some further information on this point has been obtained by the use of cuttings from sources other than those indicated above. It appeared that cuttings with a high carbohydrate content might be obtained from potted plants, the root growth of which was restricted. Cuttings of Common Mussel plum from such plants have repeatedly rooted to the extent of 80-90 per cent., which shows a significant increase over the numbers obtained with cuttings from vigorously vegetative stool or layer shoots. These facts provide some additional evidence in confirmation of the results obtained with other plants, to which reference has already been made.

In view of these results, attempts were made, as in the case of hardwood cuttings, to supplement the carbohydrate reserves of the plants by the addition of cane sugar. The method was the same as that described by Curtis (3) and Brompton plum and apple (Types II., IX. and XII.) were the varieties selected. The results were essentially the same as with hardwood cuttings (7). Cuttings which have been standing in water for two or three days always root less readily than controls. For example, 62 per cent. of the untreated batch of Apple Type XII. rooted, whilst only 16 per cent. of the water-treated batch became established. When 10 per cent. cane sugar solution was used instead of water, 64 per cent. of the cuttings rooted. On the other hand, every batch of all varieties tested, when treated with potassium nitrate rooted less well than the controls ; a concentration of 1 per cent. or over killed all cuttings in a few days.

Etiolation.

As the result of conversation with Prof. J. H. Priestley (see also 11, p. 12), some trials were made of softwood cuttings which were etiolated by growing in darkness. In order to produce material for these trials, layered or stooled plants of selected varieties of apples and plums were covered with large wooden boxes lined with black cloth. The method proved unsatisfactory owing to the incidence of fungi on the shoots, which died in large numbers. However, it was possible to obtain etiolated material of some plum stocks on the nursery by layering. The shoots were laid and pegged horizontally during the dormant season and were then covered with a thin layer of soil. When the young shoots appeared through the soil covering, they were of course etiolated at the base over a length of one or two inches, and material for trial was obtained by removing the mound of soil from the plants and detaching the young shoots close to the

parent stem. Thus, the bases of the cuttings were etiolated, and the upper portions, developed in light, were normal.

The results obtained over two seasons with partially etiolated cuttings of three plum varieties are given in Table IV. The control cuttings in each case were taken from the tips of ordinary layer shoots, and were green throughout their length.

TABLE IV.

Effect of Etiolation on Root Production of Softwood Cuttings of Plums.

Variety.	Per cent. Rooted in Sand.		Per cent. Rooted in other Substrates.	
	Control.	Etiolated.	Control.	Etiolated.
Pershore	0	4	0	0
Brompton	3	32	10	60
Brompton	0	20	0	20
Common Mussel	0	56	3	76
Common Mussel	20	30	0	17

The figures show a marked difference in favour of the etiolated cuttings, and this result is similar to those obtained by Reed (12) and by Smith (16). Smith considers that the effect of etiolation on *Clematis* is to alter the nutrition of the cutting by adjustment of the carbohydrate-nitrogen ratio, and found no evidence of any influence of the starch sheath, which Priestley (l.c.) regards as important in connection with root regeneration. Reed on the other hand, found that etiolation altered the mechanical structure by reducing the development of hard pericyclic tissues and thus decreasing the resistance to penetration by the developing roots.

With the plum cuttings in the present experiment, there was a striking difference between the rooting processes of the normal and the etiolated individual. A normal plum cutting produces a callus at the basal end and the first roots appear through this callus. Occasionally a root is found a millimetre or two above the callus, but although two inches of the cutting may have been below the level of the sand, the stem is free of roots except in the immediate region of the basal callus. The etiolated cuttings were planted with the etiolated portion below, and the green portion above the level of the substratum. Roots were developed at several points on the etiolated portion of the stem. There were no roots at the extreme end and the callus was insignificant or absent. These facts suggest that the two types of rooting are of totally different nature. In the case of the normal cutting the roots appear to be produced in response to the wound stimulus applied in making the basal cut ; such roots have been termed " wound roots " by van der Lek (8). The roots from the etiolated stem, on the other hand,

are apparently of the nature of the "morphological roots" of van der Lek. Swingle (18) holds the view that the development of such "morphological roots" from pre-existing root meristems does not constitute true regeneration, but it is to be regarded rather as the extension of organs already differentiated.

In view of the marked difference in the type of the root development in the two cases, it is difficult to believe that the effect of etiolation was merely to alter the proportions of nutrient materials in the manner suggested by Smith for *Clematis*. Furthermore, since in the present case the apical region of the cutting was exposed to normal conditions of illumination for a fortnight or more immediately before planting, it is hardly likely that the carbohydrate-nitrogen ratio was very different from that of normal cuttings. It seems more probable that other physiological conditions or structural differences were responsible for the different behaviour of the two types of cutting. Either etiolation favours the production of root initials, or else modifies the stem in such a manner as to facilitate their further development as suggested by Priestley and by Reed; it has not yet been possible to investigate this point.

Not only are roots more easily produced from etiolated than from green stems in the form of cuttings, but the same difference exists when the stems are still attached to the parent plant, and this fact is employed in the propagation of plums by the layering method. The stools of apples, quinces, etc., from which young rooted plants are to be obtained are denuded of shoots in the winter. The stool is then generally left exposed, and a crop of young adventitious shoots appears in the spring. Soil is "mounded" around these at intervals, so that their bases are covered, but the upper portions are always exposed. Roots are developed on the region of the stem which is covered by the soil although this portion is not etiolated, having developed in light prior to "earthing up." If this method is applied to layered shoots of plum varieties it is found that only a small number of the shoots develop roots, and in fact the method is not satisfactory from a commercial point of view. If, however, the laid shoots are thinly covered with soil before the commencement of spring growth, as described by Hatton (5, p. 20), a much greater proportion of the shoots, which are etiolated at the base, become satisfactorily rooted. Unfortunately, when the laid shoots are covered previous to the emergence of new growths, the number of the latter is smaller than when the layer is left exposed, but the increase in the number which produce roots is in many cases sufficient to compensate for this.

The Season.

It is, of course, advantageous from a nursery standpoint to plant softwood cuttings as early in the year as they can be obtained, so that the plants may have as long a growing season as possible. This increases the chance of their becoming

large enough to bud in the following season. Difficulty is encountered, however, in obtaining cuttings in large quantity early in the season, since the supply is governed by the new growth of the parent plants. Some trials have been conducted to determine to what extent successful propagation is influenced by the season at which the cuttings are taken. It was considered likely that cuttings taken early in the season would be relatively rich in nitrogen and poor in carbohydrates, owing to the short time during which they had been assimilating. Cuttings taken later might be expected to be richer in carbohydrates, and should therefore root more readily if the principles already deduced from work on tomatoes are generally applicable. Cuttings were accordingly taken from similar sources at different times during the summer and were treated similarly as far as possible. It must be recognised, however, that the very nature of the experiment makes it impossible to maintain the environment exactly similar for all batches. Differences of temperature, humidity and illumination are unavoidable when the cuttings are planted at different times. However, the results have been consistent and presumably the variation of external conditions has not been significant. Table V. gives the average figures obtained from batches of cuttings planted between the dates indicated. The experiment has been carried out during two seasons with batches of from 20 to 230 cuttings, and as the different varieties were not planted on the same dates, the *exact* date of planting, which in any case has but little significance, is not given.

TABLE V.

Rooting of Softwood Cuttings Planted at Different Dates.

Variety.	Time of Planting and Per cent. Rooting.		
	Before July 5th.	July 23rd-31st.	Aug. 10th-16th.
APPLE.			
Stock Type XII.	70	12	—
PLUMS.			
Brompton	17	16	3
Common Mussel	7	2	2
Pershore	1	0	0

In these series, Common Mussel rooted very badly; a much higher percentage is usually obtained with this variety. As in all these experiments, the demands on space have made it necessary to remove the cuttings from the frames as soon as possible in order to make room for other trials. Thus at the time the records are taken a large number of cuttings, although still alive, have not yet produced roots and are not counted as established. Many of these eventually produce roots if replanted, and if these were included the figures would show still greater differences in favour of early planting.

The result appears somewhat at variance with the view that cuttings with a high carbohydrate content root more easily than those rich in nitrogen, but it must be observed that when cuttings are planted at different periods of the growing season, not only are there differences in the internal condition of the plants, but in addition external influences vary in a seasonal cycle, and it is probable that the advantage of early planting must be attributed to environmental factors.

THE SUBSTRATUM.

The lack of accurate knowledge as to the most suitable substratum in which to plant different varieties prompted some experiments on the subject. Comparable batches of cuttings were planted at the same time in different media, and the usual records were taken. The figures in Table VI. are the averages of two or three separate trials in each case, and they express the number of cuttings rooted under each set of conditions as a percentage of the number rooted in sand.

TABLE VI.

Influence of the Substratum on the Rooting of Plum Cuttings.

Variety.	Substratum.			
	Sand.	Coconut fibre (1 part) and Medium loam (1 part).	Medium loam (3 parts) and Sand (2 parts.)	Coconut fibre (3 parts) and Sand (1 part).
Brompton	100	112	37	29
Pershore	100	27	25	0
Common Mussel	100	17	72	32
Damas C.	100	35	26	26

The superiority of sand except in the case of Brompton is quite distinct, and varietal differences are in evidence throughout the series. The loss of cuttings occurs chiefly through rotting at the base, which is probably governed by the water content of the medium and the degree of hardness of the base of the cutting. Thus different types of cutting and different varieties are able to tolerate different degrees of moisture. Sand is much less likely than the other materials used to become waterlogged, and it is probably to this fact that the success of cuttings in sand is due. This statement is not intended to exclude the influence of such factors as acidity, but circumstances attendant upon practical greenhouse technique are such that moisture conditions are often dominant.

The experiments with softwood cuttings have shown that it is possible to use this material with a certain degree of success for several varieties of fruit

tree stocks which are not easy to raise in other ways, but it is clear that the method is not capable of indiscriminate application. It remains to be seen whether the conditions necessary for the success of the method are such as to enable it to be applied in practice. Indications of the nature of some of these conditions have been obtained. For example, it appears that cuttings should not be "sappy" and in active growth, and yet they should be planted early in the season. The combination of these two requirements may prove to be a practical difficulty. The best results have repeatedly been obtained when cuttings are taken from potted plants which have been started into growth early in the spring by moving them into a greenhouse, but there are obviously limits to the use of this device in practice. It may be possible to obtain the most suitable type of cutting from plants the root action of which has been restricted by methods other than potting; this has not yet been tested. Further investigation is necessary before it is possible to decide whether the use of etiolated cuttings is of practical value. There can be little or no advantage in removing and using as softwood cuttings the partially etiolated shoots from layered or stool plants, since the majority of such shoots will root satisfactorily if left attached to the parent stems. It may be possible, however, to use portions of these etiolated shoots, detaching them in such a manner that laterals from their bases will be forced into growth. Thus the number of shoots from the layer may be not materially reduced.

Work is still in progress to elucidate some of the problems which have been suggested by the experiments, and to test varieties other than those dealt with above.

Summary.

Details are given of the results obtained from trials of hard- and softwood cuttings of varieties of apple, plum and cherry.

With softwood cuttings the greatest success has been obtained with stems not in active growth planted early in the year.

In general, sand was found to be the most suitable substratum, although there are indications that other materials are more suitable for some varieties.

Stems with etiolated bases rooted more readily than normal green cuttings.

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EXPERIMENTS UPON THE REMOVAL OF LATERAL GROWTHS ON YOUNG APPLE TREES IN SUMMER; THE EFFECT ON STEM AND ROOT DEVELOPMENT.

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It is the common practice amongst nurserymen in this country, when they are "running up" young fruit trees for standards and half-standards, to allow the young growths, which break all up the stem, to remain growing naturally, or sometimes pinched back, during the tree's early life in the nursery.

The considerations which have led to this practice are probably many. These "feathered" trees, as they are called, are very convenient for adapting to any desired height or form, and it is an expensive business to keep a clean stem, a process which may not be of any value to the tree. Tree raisers claim, on the contrary, that a stouter stem and sturdier tree result if the "feathers" are left for two or three years.

Although we were fully conscious of commercial practice, we had always developed, in our nursery, the system of keeping all the young shoots below the head of the tree (i.e., the main leader in a two year old, or main branches in a headed three year old) rubbed out. This was convenient on experimental grounds, for, where we were desiring to take a measure of annual growth, it was obviously easier to concentrate that growth into a single leader or four or five main branches rather than to let it dissipate itself all over the tree. We also thought it likely, if we prevented the "feathering" taking place on the stem, that that growth "energy" might go as an addition to the head.

Since, from several other points of view, we were studying the effect of various degrees of pruning upon the tree's roots, we decided to submit a very suitable series of nursery trees to differential treatments, in order to find out exactly what was going on in the "feathered" as compared with the "defeathered" or "clean" tree.

Material Used and Treatments Compared.

We had, at the time, in our Nursery, several adjacent rows (three feet apart) of one year old trees of Allington Pippin and Newton Wonder Apples, budded (in July, 1922) upon a series of selected very vigorous stocks (which had been planted *in situ* at one foot apart the previous February). In all, there were approximately twenty trees of each, upon nine varieties of rootstock. It was planned to run these trees up for standards, and to treat every alternate tree on

the "defeathering" method. Thus, trees, 1, 3, 5, etc., were allowed to send out normal lateral shoots on their second year stems (1923). These shoots, however, were stopped at the fifth leaf, and, if any secondary growth resulted, again at the second new leaf. This series will be referred to as the "Feathered" trees. Trees 2, 4, 6, etc., had all these growths rubbed out, as far as was practicable, as soon as they appeared. This series will be called the "Clean" or "Defeathered" series. In both cases the current season's (1924) main leader growths, which very rarely feathered appreciably, were left to extend untouched.

Thus, approximately ninety trees of Allington Pippin and ninety of Newton Wonder received each treatment, wherever available, ten trees of each on every stock being treated in each way. However, since the results obtained proved decisive and confirmatory upon every type of stock, we can from the outset consider the four groups of ninety trees as four units. We feel, however, that it is worth putting on record the fact that the dfferences between Clean and Feathered trees were very much greater on some varieties of stock than on others. Since in every case but one (i.e., Type I.) these differences are consistent for both Allington and Newton, it is at least probable that this has some significance from a root stock point of view. A glance at the Appendix, giving the complete figures, will show this.

Finally, it should be pointed out that the two varieties, with which we were working, were admirably suited to supplement one another in view of their contrasting "feathering" habits. Whilst Allington Pippin tends to make long somewhat whippy laterals profusely, Newton Wonder normally produces few laterals, but short rosettes of leaves in places, and bare patches of stem in others.

As our results will show, this was a very fortunate selection, since the variety more prone to "feathering"—Allington—demonstrates more effectively the adverse results of "defeathering."

The year was a very propitious one in the Nursery, and neither insect nor fungus attack intervened to upset the normal development of the trees.

At the end of the growing season all the trees were lifted in order, and the very greatest care was taken to preserve the roots intact as far as possible.

The sets of trees were then subjected to an analysis designed to detect the relative increment of each. Table I. summarises this analysis.

Differences in Total Weight of Tree.

The first object was to discover whether there was any difference in total weight between the feathered and clean series, and, for this purpose, the feathers had to be removed before weighing. As will be seen in Table I. (column 5, Weight of Feathers) even the clean trees were found to have grown a few side shoots, late in the season, which had been missed. These are recorded for sake of accuracy,

TABLE I.

Average Measurements and Weights, at two years, of 90 *trees " Clean " grown, and* 90 *left " Feathered " of two varieties.*

	Maiden Growth in cms.		Leader Growth during year of treatment (2nd) in cms.		Weight of whole tree without " Feathers " in grammes.		Weight of " Feathers " in grammes.		Girth at " collar " in mms.		Girth at 2 feet in mms.	
	Clean.	" Feathered."	Clean.	" Feathered."	Clean.	" Feathered."	Clean.	" Feathered."	Clean.	" Feathered."	Clean.	" Feathered."
Allington (on 9 Stocks).	97	96	96	94	456	599	21	57	64	71	42	43
Newton Wonder (on 9 Stocks). ..	98	98	87	88	513	627	14	27	70	75	44	46

but it must be remembered that they were few and far between, and had not the chance of operating throughout the season.

It is interesting to note in Table I. (column 2, Maiden Growth) that the trees started out, at least in growth, as a remarkably even series, although they had grown untouched during 1923. By the end of the second year, as is shown in Table I. (column 4, Weight of whole tree), the different treatments had very materially altered the balance in favour of the "Feathered" series. In the case of Allington Pippin, the trees which had been allowed to feather averaged 143 grammes more weight per tree; in the case of Newton Wonder, 114 grammes per tree. As will be seen later, this increase in weight cannot be accounted for by any very significant increase in growth of new head, but mainly by better developed root systems and some stem thickening. The girth of stem, taken at the collar, i.e., just above the union, appears distinctly in favour of the feathered trees. Although the actual differences are small (see Table I., column 6, girth at collar), 7 and 5 millimetres, in favour of the Feathered trees, it must be remembered that these were only two year olds. Since the difference is constant throughout the series, it must add to the significance. The difference is more obvious at the collar than at two feet.

Increment in New Leader Growth.

Finally, Table I. seems to modify if not entirely dispose of our idea that, by concentrating the growth into the head of the tree, we should get an appreciably greater length of wood there. Whilst Table I. (column 3, Leader Growth) does show a slight difference in favour of the "Clean" trees in the case of Allington Pippin, the result is reversed in the case of Newton Wonder. This may be a real difference due to the distinct types of feathering normal to the two varieties, and already described.

If the figures given in detail in the Appendix be examined in the case of Allington Pippin, it will be seen that in seven cases out of nine, the balance is in favour of the "clean" trees, but the individual differences are admittedly small, and their significance may be questioned.

Effect on Root Development.

As soon as we began to examine and compare our two series of trees, it became obvious that the "de-feathering" had acted detrimentally upon root development, and we made general notes to this effect throughout. But in order to get measurable proof of our observations, we made certain root analyses on three series of Allington Pippin trees, on three different stocks.

These can be taken as typical examples, though, all through, the Allington Pippin trees showed greater differences in root development between clean and feathered than did the Newton Wonders.

Table II. illustrates the situation well.

TABLE II.

Effect of "de-feathering" Trees, during growing season, upon Root Development.

	Total Root Spread in cm.		Weight of coarse roots in grammes.		Weight of Fibre in grammes.		Total weight of Roots in grammes.		Coarseness of Roots. Below 8 mm.		Coarseness of Roots. 8 mm. and above.	
	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."
Allington on Type X. .. (Average 5 trees each).	67	78	52	83	16	22	68	105	5	5	5	8
Allington on Type A. .. (Average of 7 trees each).	77	79	67	95	13	18	80	113	7	7	5	6
Allington on Type C. .. (Average of 5 trees each).	74	94	72	118	8	14	80	132	8	11	5	7
Average for all ..	73	84	64	99	12	18	76	117	7	8	5	7

Column 2 shows a remarkable difference in root spread of 11 cm. per tree, on the average, in favour of the Feathered Trees.

The roots were then cut off the trees and graded into "Coarse Roots" (4 mm. and above in diameter), and "Fibre" (under 4 mm. in diameter) on a definite basis. Here again, especially in the case of Coarse roots, there is a remarkable average increase of 35 grammes per tree on the Feathered series (see Table II., column 3).

The average total weight of Roots (see Table II., column 5) again shows the difference very well, i.e., 41 grammes per tree in favour of the Feathered. The last column of Table II., comparing the number of roots below and above 8 mm., seems to point to the chief increase being in the coarse roots. These effects of pruning, for "defeathering" is after all merely a form of summer pruning, during the growing season, are an extremely encouraging supplement to the results we published in our Annual Report for 1923 on "Some Factors Influencing Root Development" (see pages 113-115).

Ultimate Effect upon the Development of Transplanted Trees.

It is as yet too early to say much about the ultimate influence of these differences in the trees as they left the Nursery upon the developed trees in the orchard. Sets of approximately ten trees of each variety, on each stock, were planted out (in two positions) permanently, and were headed back to a uniform height of 4½ feet. The wood growth made subsequently, in 1925, has been measured, and the girth of each tree, at 2 feet, again taken. Table III. shows that the results are not as startling as might be anticipated, though the balance of new growth and girth increment are slightly in favour of the "Feathered" trees.

Table III.

Subsequent Effect of Nursery Treatments upon Trees after Transplanting and "Heading back" (third year).

	New Wood Growth in cms.		Girth at 2 feet in mms.	
	Clean.	"Feathered."	Clean.	"Feathered."
Allington .. .. (On 9 stocks).	164	171	49	53
Newton Wonder .. (on 8 Stocks).	128	132	54	56
Average of Both	146	152	52	55

It remains to be seen whether the differences will be accentuated or the reverse, now that all the trees are permanently defeathered below the head.

GENERAL CONCLUSIONS.

In any case, our experiments seem to have a very practical bearing on several problems. There now exists actual proof of the fact that, in order to raise the sturdiest and weightiest nursery tree, the young trees should be allowed to " feather," especially as the total residual growth is not materially increased, if the " feathers " are kept rubbed out.

From the point of view of summer pruning or pinching, so frequently recommended for restricting garden trees and those making too exuberant growth, it seems probable that, if this almost complete removal of lateral shoots has had such a marked effect, the removal of lesser portions may be expected to have some effect, and check the growth development of the tree.

Finally, whilst it is not the place here to digress into theories as to what is taking place in the tree's balance, it seems certain that these results will add at least one more link in the chain of experiments designed to study the root shoot ratio in such plants. The striking gradation of effect shown most in root weight and development, then in stem increment at the collar, less at two feet and least of all in the growth of head is very suggestive.

The writers would especially like to thank Messrs. F. Cheal and M. Tydeman who were closely associated with them in taking the somewhat elaborate and detailed records, on so considerable a series of trees. Their thanks are also due to Dr. R. C. Knight, for his general interest and advice and to Mr. N. H. Grubb for giving the time to work out many of the " probable errors." This enables them to add the following paragraph dealing with the measure of reliability of the figures and to indicate the " probable errors " for individual groups of trees, for several of the most important records.

RELIABILITY OF THE FIGURES.

Appendix B, Tables a and b, gives the figures for the sets of trees of Allington Pippin and Newton Wonder on each variety of root stock separately, together with their Probable Error. The size of these probable errors is extremely encouraging when the comparatively small numbers of trees is taken into account.

In the case of Table a, average weight in oz. per tree, if we adhere to the standard we have suggested elsewhere, and ignore those experimental differences which are less than 3.2 times their probable errors, we find that 11 out of 18 series still show significant differences in favour of the Feathered trees. (These are shown on the Table in Black Type.) The differences range from 3.3 times the probable error up to 7.5 times, so that the chances in favour of a repetition of the results under similar conditions are very large. Three other cases come very close to our standard.

If the individual tree figures for the two series (clean and feathered) be taken for each variety (Allington and Newton) on all stocks, and if the weight of each tree is expressed as a percentage of the mean or average of the Clean series for its particular stock, the probable errors are still further reduced and the significance greatly enhanced.

In the case of Allington, where series of 85 and 79 trees are actually compared, the difference in favour of the feathered series works out at 14 times its probable error.

Even in the case of Newton Wonder, where series of 82 and 77 trees are being compared, and where smaller differences were to be expected, the difference is still over 8 times the probable error.

Again, if we examine the average girth at collar in mm. given in Table b, we find the statistical analysis again encouraging. Here out of 18 actual differences, no less than 12 stand our criterion of showing differences ranging from 3.4 to 8.2 times their probable errors. Two further cases come very near to being significant.

If, as before, the individual trees in each series are brought to a " common denominator " for comparison, the reliability of the experiment is still further emphasised, the difference working out at 12 and 9 times their probable errors, for sets of trees of 85 and 79 and 82 and 77 respectively for Allington and Newton.

Since the actual differences in the case of " girth at two feet " and of " new leader growth " were so small and inconsistent, it was not felt worth while to examine these figures in greater detail.

Summary.

1. The " Defeathering " in summer of the stems of young trees has been shown to affect the tree's weight and girth adversely.

2. This " defeathering " also much restricts the development of the tree's roots.

3. On the other hand, it seems clear that the remaining leader growths are not very materially strengthened.

4. Generally, trees allowed to feather in the nursery, show some slight gain in growth the year after transplanting.

5. These facts have a practical application both in the raising of young trees, and summer pinching practices. They also shed some light on theoretical considerations of the root shoot ratio.

APPENDIX A.

Details Compared for each Treatment on each Stock.

ALLINGTON PIPPIN (units of approx. 10 trees).

On Stock Type.	Maiden Length before treatments.		Second Year growth.		Total Weight.		Girth at Collar.		Girth at 2 ft.	
	Clean.	Feathered.	Clean.	Feathered.	Clean.	Feathered.	Clean.	Feathered.	Clean.	Feathered.
I.	102	101	95	84	48	66	64	73	43	46
X.	96	101	87	85	40	57	61	70	39	44
XII.	90	92	103	95	48	63	66	73	41	43
XIII.	91	87	111	102	51	57	63	67	41	40
XV.	100	98	86	105	43	57	62	72	39	42
XVI.	92	93	100	100	43	54	63	69	40	41
A.	99	97	101	98	48	63	65	71	42	44
C.	98	94	91	84	48	60	65	71	44	43
F.	104	105	94	89	51	66	67	75	45	44
Average	**97**	**96**	**96**	**94**	**46**	**60**	**64**	**71**	**42**	**43**
				NEWTON WONDER.						
I.	97	98	83	76	57	60	71	74	47	47
X.	94	94	80	85	51	66	66	72	42	47
XII.	100	101	105	93	51	68	75	77	46	46
XIII.	93	88	88	90	54	63	69	73	43	42
XV.	95	100	80	92	46	63	67	76	40	44
XVI.	94	95	88	89	48	60	68	76	42	45
A.	95	97	91	92	51	60	70	72	44	47
C.	102	100	86	91	51	57	69	74	44	46
F.	108	110	77	79	57	66	73	80	46	46
Average	**98**	**98**	**87**	**88**	**51**	**63**	**70**	**75**	**44**	**46**

APPENDIX B.

Figures for Sets of Trees on each Variety of Stock separately, with Probable Errors.

Table a.—Average weight in oz. of Tree.

ALLINGTON on : Stock	Unit of Trees.	Clean.	Unit of Trees.	Feathered (minus feathers).
I.	(9)	17.3±.51	(7)	22.6± .73
X.	(10)	14.2±.68	(9)	20.4± .48
XII.	(10)	17.0±.85	(9)	22.2±1.08
XIII.	(11)	17.7±.63	(10)	20.0± .75
XV.	(9)	15.1±.44	(9)	20.3± .73
XVI. ..	(10)	14.8±.47	(9)	19.0± .89
A.	(10)	17.2±.55	(10)	21.6± .91
C.	(9)	16.8±.61	(9)	21.0±1.09
F.	(7)	18.4±.41	(7)	23.4± .67
NEWTON WONDER on : Stock				
I.	(9)	20.0±.79	(9)	20.9± .97
X.	(9)	17.7±.81	(9)	22.8± .68
XII.	(7)	20.3±.84	(7)	24.0± .87
XIII.	(9)	19.2±.74	(9)	21.6± .81
XV.	(9)	16.4±.90	(9)	21.9±1.06
XVI.	(10)	17.2±.74	(9)	20.9± .87
A.	(10)	18.3±.90	(9)	21.1±1.22
C.	(10)	17.5±.64	(10)	19.9± .59
F.	(9)	20.1±.82	(6)	22.7± .77

Table b.—Average Girth at "Collar" in mm.

ALLINGTON on : Stock	Unit of Trees.	Clean.	Unit of Trees.	Feathered.
I.	(9)	64.0± .93	(7)	72.9±1.54
X.	(10)	60.6±1.62	(9)	69.7±1.08
XII.	(10)	66.0±1.67	(9)	72.7±1.70
XIII.	(11)	63.3±1.23	(10)	66.9± .93
XV.	(9)	62.2± .78	(9)	71.9± .89
XVI.	(10)	62.5± .88	(9)	68.6±1.53
A.	(10)	65.2± .61	(10)	70.8±1.49
C.	(9)	65.4± .51	(9)	70.9±1.33
F.	(7)	66.6± .46	(7)	74.0±1.13
NEWTON WONDER on : Stock				
I.	(9)	71.1±1.05	(9)	74.3±1.37
X.	(9)	66.2± .92	(9)	71.9± .38
XII.	(7)	74.7± .82	(7)	77.3± .73
XIII.	(9)	69.2± .92	(9)	73.3±1.14
XV.	(9)	66.8±1.61	(9)	76.1±1.99
XVI.	(10)	67.9±1.03	(9)	76.0± .78
A.	(10)	70.2±1.53	(9)	72.4±1.66
C.	(10)	68.5± .93	(10)	73.5± .89
F.	(9)	73.1±1.29	(6)	79.8±1.36

THE RELATION IN THE APPLE BETWEEN THE DEVELOPMENT OF YOUNG SHOOTS AND THE THICKENING OF OLDER STEMS.

By R. C. KNIGHT.

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In the course of an examination of some anatomical features of young stems of the apple at different seasons of the year, it was observed that in spring the new xylem which was being formed was often distributed irregularly over the length of the stem. At some levels a considerable extension of girth had taken place, whilst at the same period, other regions of the same stem showed little or no sign of new wood. Frequently, also, the new tissue was not evenly distributed at any one level, but was very much more extensive on one side than on the other. Later in the season these irregularities ceased to be so obvious and, apart from its natural taper, the stem appeared to be fairly evenly thickened throughout its length. As a result of this observation, a large number of apple stems have been examined at different stages of growth and some facts have been observed which throw light on certain growth responses to pruning which have been reported from experiments in the field.

The phenomena observed may be summarised in the statement that when dormant buds break into new growth in the spring, the new xylem appears first in regions bearing such developing buds. Thickening of regions of the stem which do not carry active buds begins only at a later stage, spreading progressively from the vicinity of the new shoots. During the normal development of a one-year old unpruned shoot, the apical bud is the first to begin growth and it is followed by the lateral buds close below it. The apical bud usually forms the strongest shoot and the lateral shoots are progressively weaker the farther they are from the apex, until, when the lower end of the stem is reached, the buds either form very short leafy " spurs " or remain entirely dormant. When this type of growth occurs, new thickening begins immediately below each of the growing new shoots and spreads downwards to the " bare " regions of the stem. Thus by the time thickening has just begun in the portion of the stem bearing no secondary shoots, the upper region near the new shoots shows several layers of new xylem elements. The process is most obvious in the stems of varieties which normally produce considerable lengths of " bare wood," that is, varieties in which many buds remain dormant.

When a large number of the upper buds break into active growth each contributes its share towards thickening the stem and the circumstances are also

complicated by the presence of spurs. The process can, however, be very much simplified by removing during the dormant season all buds from a stem except one or two near the apex. When these buds have produced shoots a few centimetres in length, the progressive decrease in the amount of new thickening from apex to base can easily be seen. The details of such a shoot are shown in Plate I. All the buds except two close to the apex were removed from the shoot in the winter, and on June 1st, the stem was sectioned at various levels as indicated in the fig 1. The sections (fig. 2 A—C) show the extent of the new xylem at points denoted by the lettering. At A, just below the new shoots, a large mass of new tissue has already been added, whilst at B, there is a smaller increase. At C, some 25 nodes from the apex, only one or two rows of new wood have been added, and the decrease is found to be progressive throughout the shoot. About the middle of May, such a shoot shows the thickening just begun near the apex, whilst lower down the stem no new xylem at all is visible.

With some varieties it frequently happens that a few buds near the apex develop into new shoots whilst several buds below remain dormant, and still further down the stem, one, or perhaps two buds grow into fairly strong shoots and below these again no new laterals develop; such a shoot as this shows very clearly the association of new thickening with the growing shoots. Near its apex, considerable thickening occurs; the extent of the new tissue decreases with increasing distance from the apex until the lower developing laterals are reached, when more new wood is visible, and this decreases again when the lower dormant buds are reached.

In the region of a strong lateral shoot the greatest quantity of new wood is found not only at the same level as the new shoot but also on the same side of the parent stem. Thus in early June, the new thickening forms a crescent on one side of the old xylem, and if more than one lateral shoot is present, a corresponding number of crescents of new wood may be found. Plate 2 shows the development of a shoot "disbudded" in order to produce such crescents. In this case, about six inches of the apex of the stem was removed in winter and the uppermost remaining bud was left to develop. The next twelve buds were removed while the fourteenth and fifteenth were untouched. Below these again all buds were removed. Thus a strong shoot developed from the uppermost bud, which was actually a lateral, and shoots also developed from the fourteenth and fifteenth buds. On June 1st, a large crescent of new wood had developed in the internode below the top shoot (fig 4A). The size of this crescent decreased at lower levels until the fourteenth bud was reached (fig 4B), and below the fifteenth bud a second small crescent of new elements appeared (fig 4C). It is probable that the larger crescent in C includes some wood associated with the shoot of bud fourteen as well as that associated with the uppermost shoot. Below these shoots a further decrease in new wood was observed.

It is significant that the section fig. 4B, immediately above the shoots fourteen and fifteen, shows no sign of the small crescent which is visible in C. This denotes that whilst the thickening has spread downwards from these shoots, it had not, at this stage, spread very far upwards. The distribution of new thickening in relation to the new shoot at a later stage is shown by some figures obtained on June 21st from a shoot the upper and lower buds of which were removed when dormant. One bud only, about 30 cm. from the apex, was allowed to grow and when this bud had produced a shoot 20 cm. long, sections of the parent stem were cut at points 1 cm. above and 1 cm. below the new shoot. These sections were drawn in outline with a projection ocular and the areas of the cross section of the new and the old wood were measured with a planimeter. The results were as follows :—

	Cross sectional Area ($cm.^2$) of:		%
	1925 Wood.	1926 Wood.	Increase
Above new shoot	0.086	0.014	17
Below new shoot	0.110	0.060	55

It is quite clear from this that although thickening had begun at a point 1 cm. above the new shoot, both the actual and the relative extent of this thickening was much less than the increase in size at a point the same distance below the shoot.

Although small masses of new xylem arise in the stem near the base of the bud practically simultaneously with the commencement of growth by the latter, there appears to be no doubt as to the physiological sequence of the two phenomena. Following the development of an upper bud, new xylem soon appears very close to dormant buds immediately below, but these do not respond by breaking into growth. On the other hand, wherever bud-growth occurs, new xylem formation invariably accompanies it. This indicates that the new wood is laid down as a result of bud development and that the latter process is not a consequence of the proximity of new thickening.

The process of the development of new thickening appears thus to be dependent upon some products of young growing shoots. The region nearest these shoots, owing to its position, is most favourably situated for obtaining these products and it is the first to begin to expand. It is only when the requirements of this portion of the stem are provided for, that supplies are available for other regions. Further, the tissues directly below a shoot are more readily supplied than those above, and even the lower portions of the parent stem which are not vertically below the new shoot, receive their first supplies relatively late. The whole process may be visualised as a wave flowing along a course vertically downwards, but overflowing laterally and upwards as its volume increases.

The physiological processes involved in the lignification of cells formed on the inner side of the vascular cambium are of a distinct character. Lignification of a cell involves the death of the protoplast and addition of material to the cell walls. The substance of the protoplast disappears, presumably as the result of catabolic activity, and in consequence, nitrogenous substances must be produced and are probably available for re-synthesis by adjacent living cells. The increase in thickness of the cell walls utilises large quantities of materials of carbohydrate nature, such as are being manufactured in the new leaves. It appears therefore, that the formation of new wood elements, involving the release of nitrogenous substances and the consumption of carbohydrates, is closely associated with, and dependent upon the development of young leafy shoots on account of the carbohydrates which the new shoots supply.

In experiments upon root formation by stem cuttings, van der Lek (2) found that in some circumstances the amount of root production was largely determined by the development of the leaf buds, and he is of the opinion that the growing bud produces a substance of the nature of a hormone which stimulates root growth. It is possible that the phenomena described above may be explained in a similar manner, and it may be urged that the process of lignification does not depend upon new shoots for a supply of carbohydrates, but that on the contrary, these substances are available in the form of starch stored in the stem. Furthermore, the process of stem-thickening is not merely one of lignification, for it also involves the activity of the cambium for the production of new cells, the lignification of which is merely an after effect; it is not clear how cell division in the cambium could be induced by the presence of carbohydrate supplies formed by new leafy shoots. It is possible that stimulation by a hormone and the availability of carbohydrates are complementary in their influence on the process of new xylem production.

The association of the growth of new shoots with the formation of new xylem in the parent stem has a direct bearing on the effect upon subsequent growth of the removal of lateral shoots from young trees. Results of experiments bearing on this question are reported by Hatton and Amos (1). They found that if lateral shoots as they appeared were removed from the stems of a young tree, there was a very definite effect upon the growth of the tree in the course of the season. This effect appeared to be graded, and increased from above downwards. The size of the head of the tree was unaltered by the pruning treatment, whilst only a slight effect was observed on the stem-girth two feet from the ground. The girth at the base of the stem, however, was reduced by some 10 per cent. by the removal of the laterals, whilst the weight of the roots was very much less in the " defeathered " trees than in the untreated series. These results can be explained in terms of the facts concerning new thickening and new stem growth recorded in the present paper. Since the

thickening of a stem begins in the region of buds which are developing into new shoots and spreads downwards from these, it is evident that increase in size of the base of a stem from which growing shoots are removed, will not begin so early in the season as that of the base of a stem carrying its normal laterals. In the former case the base of the stem is much further from developing new shoots than in the latter, and the downward spread of the thickening takes longer to reach the base. Consequently, the lower portion of the stem free from laterals is expanding during a shorter period than the base of a normally "feathered" stem; the result is a greater total thickening of the latter.

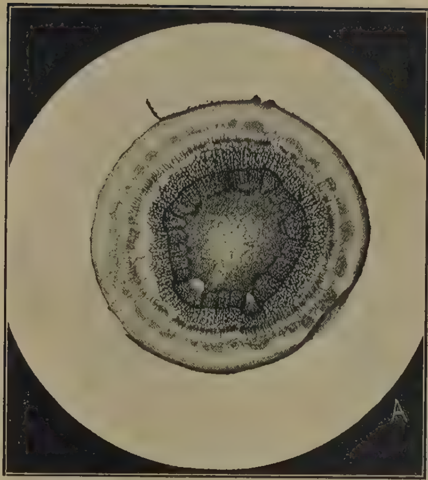
The influence of lateral pruning upon the girth of the stem at the two-foot level can also be correlated with the facts in the present paper. Information kindly supplied by the authors referred to, indicates that the laterals appearing on the stem below the two-foot level were both more numerous and more vigorous than those growing above. Since the spread of the thickening is primarily downwards and only secondarily upwards, it is to be expected that the girth at two feet is chiefly influenced by the laterals above that level; these were few, and the resulting difference in girth was less marked at that point than near the base. This reasoning is also capable of extension to the head of the tree, which, being above all the stem-laterals, is uninfluenced by their removal.

The question of the effect of the removal of laterals on root development is really beyond the scope of this paper, but the mechanism producing the effect is apparently similar to that under discussion. Carbohydrate materials for root-formation must come from the leaves, and the effect of preventing the growth of laterals is, in effect, to remove the source of new carbohydrate supply farther from the roots. It is reasonable to suppose that the carbohydrates are more readily available at points near the source of supply than in regions farther removed. Consequently, the downward gradation of the thickening process is probably continuous, and expansion of the roots will begin still later than girth-increase at the base of the stem. Similarly if the extension of the root-system is dependent upon a hormone formed during stem growth, as van der Lek suggests, lateral pruning delays the arrival of the hormone at the root meristems and the commencement of growth is postponed.

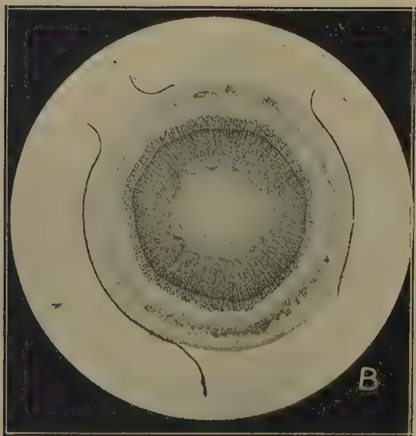
Thus the effect of the pruning treatment upon the season's root-increase will be more marked than the effect upon the stem expansion. It is perhaps significant that the presence of laterals on the stem appears to affect the root development chiefly by increasing the thickness of individual roots, as indicated in Table II. of the paper by Hatton and Amos. This affords additional evidence of the continuous nature of the downward spread of the commencement of new thickening not only from one region of the stem to another, but also from stem to roots.

PLATE I.

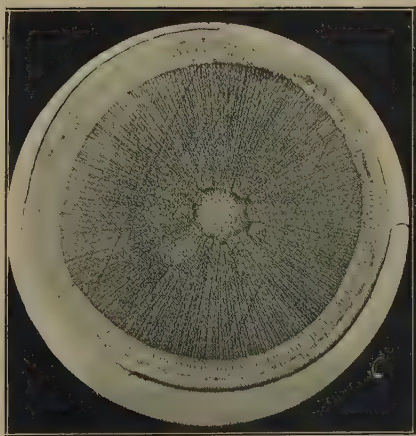
1.



2A.



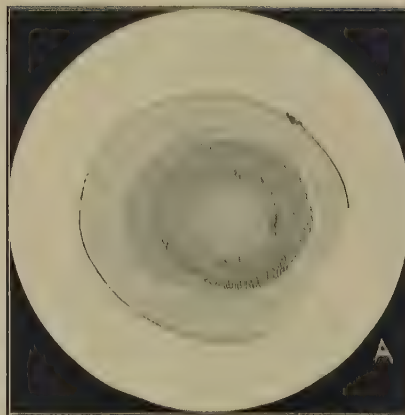
2B



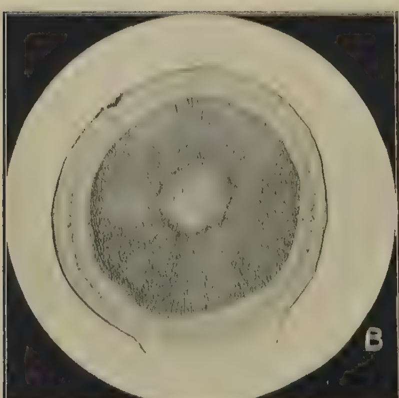
2C.

PLATE II.

3



4A



4B

4C

SUMMARY.

In Spring new wood formation in the stem of the apple begins in close proximity to a developing shoot and spreads vertically downwards. Upward and lateral spread of such thickening occurs only later.

These facts throw light on the growth responses to certain pruning operations.

EXPLANATION OF PLATES.

Plate I. Distribution of new thickening of apple stem when only upper buds develop.

Fig. 1. Shoot showing positions at which sections 2 A—C were cut.

Figs. 2 A—C. Sections cut at levels A, B, C of Fig. 1.

Plate II. Distribution of new thickening of apple stems when lateral buds develop.

Fig. 3. Shoot showing positions at which sections 3 A—C were cut.

Figs. 4 A—C. Sections cut at levels A, B, C of Fig. 3.

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(1) *Hatton, R. G. and Amos, J.* Experiments upon the Removal of Lateral Growths on Young Apple Trees in Summer ; the Effect on Stem and Root Development. Journ. Pomology 1927. VI. 1.

(2) *Van der Lek, H. A. A.* Over de Wortelvorming van Houtige Stekken. Meded. v. d. Landbouwhoogeschool te Wageningen, 1925, 28, 1-230.

BOOK REVIEW.

PLANT NUTRITION AND CROP PRODUCTION.

By E. J. Russell (University of California Press, Berkeley, California, 1926).

As stated in the Foreword, the volume embodies the Hitchcock lectures for 1924, delivered by Sir John Russell in the University of California.

Five lectures were given and in the book these appear as five chapters.

The first chapter deals with the subject of "The Study of Plant Nutrients." In this the author outlines the historical development of our knowledge of plant nutrition. Commencing with the simple ideas and experiments of Thales, Van Helmont, Glauber, Home, etc., he shows how, eventually, a tangled mass of observations accrued, which led to considerable confusion of ideas, and from which emerged order and advancement in knowledge by the brilliant labours of De Saussure, Boussingault, Liebig and Lawes and Gilbert. From the early work of these latter workers, the broad principles of plant nutrition were established.

From this latter point, it is shown how the intricacies of the apparently simple problem have developed, the manner in which modern workers have grappled with these and the measure of success and the degree of practical advancement to the industry and to mankind which have resulted.

The second chapter, which deals with "Positive Science and Exact Demonstration," is both novel and interesting. It deals chiefly with the attempts which are being made to treat mathematically the data of plant growth studies. The old idea of Liebig of "diminishing returns," and the later ideas of Mitscherlich, Baule, Prescott, etc., which are represented graphically by logarithmic and sigmoid curves and the surface model, are discussed and points which have been elucidated by the statistical studies of R. A. Fisher at Rothamsted are presented in illustration of the progress which has been made in the endeavour to express quantitatively the effects of the various factors determining crop yields. The point is stressed that the end point in all studies in agricultural science should be the mathematical expression of the results and it is shown how each new problem which arises must of necessity pass through many phases involving division and subdivision into its numerous compartments.

The processes concerned in the decay of organic residues and their subsequent conversion to plant food materials, so far as these are known, are treated in the third chapter.

After describing the main processes, of which the products are humus, nitrates and carbon dioxide, the author traces in a fascinating way the development of ideas from the time of the classical experiments of Schloesing and Muntz to the present time. Here, again, it is shown how the first simple problem has been developed and elaborated, divided and subdivided, and how at the present

time workers in many branches of science are engaged in attempting to piece together the story of the activities of the soil population. In the closing section, the complexity of the problems involved are illustrated by the description of some of the elaborate researches which have been carried out at Rothamsted and elsewhere on the activities and relationships of soil bacteria and soil protozoa.

The fourth chapter, dealing with "The Soil Micro-organisms: Can they be Controlled and Utilised?" should prove of great interest both to scientific workers in agriculture and to practical agriculturists.

It illustrates in vivid fashion the tremendous economic importance attaching to the controlling of the teeming population of the soil.

The three methods hitherto used in attempting to utilise and direct the activities of the soil organisms are stated and accounts are given of present-day commercial applications of the knowledge which has accrued from researches in the past, among which may be mentioned the following: lucerne inoculation, partial sterilisation of glasshouse soils, use of sugar for fixing nitrogen in sugar plantation soils, manufacture of artificial farmyard manure, treatment of potato scab, etc.

The closing chapter is devoted to discussing the relationship between the soil and the living plant. The processes of soil formation from rock fragments are described and it is shown how the soil is the resultant of the effects of climatic conditions and complex cycles of the activities of plants and micro-organisms. Modern views on the nature of and the importance and functions of the soil colloids are discussed and the subjects of pore space, soil atmosphere and the soil solution are treated in relation to the existing state of knowledge. Readers who are unacquainted with the researches of Gedroiz, Hissink, Bradfield, Kelly, etc., will find this chapter of absorbing interest.

The chapter concludes with a summary showing that the reactions occurring in the soil, both organic and inorganic, are extremely complex and that the growing crop in the field is the resultant of these.

The book contains numerous plates, diagrams and tables and in all cases these are well executed. A pleasing feature of the plates is that there are among them several which will be greatly prized by everyone connected with Agricultural Science—photographs of Lawes, Gilbert, Liebig, Boussingault; the Manor House at Rothamsted, the barn at Rothamsted used as a laboratory, 1842 to 1852, the Rothamsted Laboratory demolished 1914, pages from the note books of Lawes and Gilbert.

The following errors occur in the text:

Page 43, "reacted" for "reached"; page 48, "opposite page 5" for "opposite page 52"; page 50, "figures 17 and 9" for "figures 17 and 18"; page 66, footnote, "this curious phenomena" for "this curious phenomenon"; page 69, "mirco-organism" for "micro-organism."

The volume should prove of great interest to all scientific workers who are engaged in problems relating to plant nutrition and also to practical agriculturists who desire to understand the causes of the successes and failures of their everyday labours.

Those who are tempted to read the book are assured of an extremely enjoyable as well as a profitable time.

It has especial value to the agricultural scientist because of the historical treatment of the various subjects and of showing the present stage of knowledge in the various branches of agricultural science relating to crop production.

T. Wallace.

STUDIES IN THE ROOT AND SHOOT DEVELOPMENT OF THE STRAWBERRY.

II.

NORMAL DEVELOPMENT IN THE SECOND YEAR.

By C. E. T. MANN and E. BALL,

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I.—INTRODUCTION.

In a previous communication to this Journal "Studies in the Root and Shoot Growth of the Strawberry.—I.," an outline was given of the scheme of work proposed on this subject. It was stated that a portion of the investigation would consist in tracing the life history of the cultivated strawberry from the date of planting the runner through a number of consecutive seasons. A full account was given of the observations made during the twelve months after planting, a series of deblossomed plants being compared with the cropped plants of the "normal series." In this paper it is proposed to set out and discuss the observations made in 1925-1926, the second year of the plants' growth.

II.—METHODS.

Material for examination was obtained from the plants set out in September, 1924, as described in the previous paper. In this season, however, five plants were raised at each examination instead of ten. It was found that the smaller number gave equally satisfactory results if care was taken each time to select plants of the average range of vigour. Similar observations to those made in the season 1924-1925 were made and quantitative data were again obtained.

III.—RESULTS FOR SEASON 1925-26.

(I.) The Normal Development of the Strawberry from October 19th, 1925, to October 21st, 1926.

October 19th. 59.1 weeks from planting.

Growth of new "primary" roots and of secondary roots was still taking place vigorously. The average length of the longest new root per plant was approximately 17.3 cms. The new daughter crowns were still growing and new leaves were unfolding. As yet only the outermost leaves of the plants showed any signs of autumn tints.

December 1st. 65.2 weeks from planting. (Plate I., Figs. 1 and 2.)

*(1) The runner roots, (2) the autumn-formed roots, and (3) the spring-formed roots were distinctly darker in colour than when last examined, and most of the finer roots were now quite brown or dead. Owing to this loss of the fine roots the bulk of the three types of roots was appreciably smaller. (4) Only a few new main roots had developed since October 19th, those already present on that date had increased in length and markedly in thickness. The earliest formed new primary roots were quite well furnished with lateral roots and were of a darker yellow colour than those which had developed more recently. The former were mainly borne on the main crowns while the latter had generally been developed by the new daughter crowns. The average length of the longest new primary root per plant was now approximately 17.6 cm.

The older leaves had mostly fallen off or were ragged, brittle and red in colour. All the young leaves were small, of a bluish-green colour, and had short petioles. The average number of crowns per plant was 5.8.

January 11th. 7.11 weeks from planting. (Plate I., Fig. 3.)

Some slight root growth had taken place in the past six weeks. A few new primary roots had developed and some others had grown in length. The later formed ones were still devoid of fine roots. (1) The runner-roots, (2) the autumn-formed roots, and (3) the spring-formed roots were still alive and vigorous and had produced a few new secondary roots. Many of the finer roots had rotted away. Plate II., Fig. 1 shows the condition of the root system at this date and the autumn-formed primary roots, as yet unfurnished with secondary and tertiary roots, can very easily be distinguished from the older roots by the difference in colour.

The aerial portion of the plants was now noticeably small compared with the crown and the root system. The large number of dead leaves was very noticeable.

February 17th. 76.3 weeks from planting.

Very little root growth had taken place since January. Some slight growth of fibrous roots had taken place.

Shoot growth had just commenced—each crown bearing one or two new leaves which were just unfolding. These new leaves were different in colour from the older leaves being yellowish green instead of bluish green. A few flower trusses were just visible on careful examination.

* For the classification of the different types of root see Journ. of Pomol., Vol. V., No. 3, p. 156.

March 16th. 83.2 weeks from planting.

Root systems 1, 2, and 3 were at this date yellowish brown in colour, showing that the loss of cortex was now complete and the cork exposed. A few "feeding" roots were still borne by these roots. (4) The autumn-formed roots were still yellowish-white in colour, no secondary thickening having yet taken place. Many of them were still comparatively unfurnished with fine roots although the commencement of the growth of feeding roots was now observable. A few new main roots had been produced and were developed on the weaker daughter crowns which had poor root systems—indicating again the supplementary nature of the spring growth of main roots. (*loc. cit.*, p. 155.)

Much growth of the aerial portion of the plant had taken place and it was noticed that the condition of the plants was about one month in advance of that of the previous season.

April 26th. 86.1 weeks from planting. (Plate II., Fig. 2.)

The older roots (1, 2 and 3) were yellow in colour and bore a few fine roots at the extremities of the branches. (4) The new roots had produced much fibrous root, the most noticeable feature at this date. Brown patches were seen on these main roots, indicating that secondary thickening had commenced. The new primary roots had their origin higher up on the crowns than the older ones.

Considerable growth of foliage and flower trusses had taken place, the latter now having long stalks with the primary flowers just expanding.

June 7th. 92.1 weeks from planting.

Very little change had taken place in the external appearance of the root system since April. Very few new primary roots had been formed in the Spring, the main growth being of lateral roots. The autumn-formed roots were slightly more brown.

Considerable growth of foliage had taken place. Practically all the flowers had set fruit, many of which were by now as large as a pea. "Runner" growth had commenced and the longest stolons were about 30 cms. in length.

July 19th. 98.1 weeks from planting.

The roots formed in the past autumn and spring had become darker in colour. The chief feature of interest was the commencement of the formation of the second post-cropping root system, i.e., of the root system formed during the late summer and autumn.

New leaves were still unfolding and the older ones were becoming brittle. Considerable growth of runners had taken place and the stolons were now up to 1 yard in length. No new crowns were yet visible.

August 18th. 102.5 weeks from planting.

A slight further growth of new main roots had taken place since mid-July.

At this date five average plants had forty-three old crowns and forty-one new ones which had been formed since midsummer.

September 14th. 106.4 weeks from planting.

The growth of new primary roots since mid-August was very marked, each plant now having a considerable bulk of them. These new primary roots had their origin on the old crowns as well as on those formed since the end of July. It was noticed that as in 1925, those new roots had their origin higher up on the crowns than those which had been formed previously, i.e., in the autumn of 1925. The old main roots which by this time were quite black, had increased considerably in thickness.

Several new crowns had been formed since the last examination.

October 21st. 111.6 weeks from planting.

Considerable further growth of primary roots and of lateral roots had taken place. The original runner roots were still living and bore living lateral roots. These old roots were quite black but on scraping away the old dead outer tissue a white area of living tissue could be seen. It was of interest to note that none of the old main roots had died up to date—loss of the finer feeding roots had occurred and the cortex had become black and dead, but the internal tissues were still living.

The daughter crowns had grown considerably since mid-September, and most of them were by this time furnished with primary roots. Considerable death of old leaves had taken place, but new ones were still unfolding.

Deblossomed Plants.

On October 19th the root system formed since midsummer was more vigorous than that of the cropped plants and the leaves showed less autumn colouring, the shoot growth on the whole being more vigorous. Observations made in early December showed that this difference in vigour was still maintained. The older roots were less black, bore more lateral roots and the bulk of the new roots formed since midsummer was greater. By February 17th the difference in vigour between cropped and deblossomed plants was less marked, and from this date gradually became less until by April 26th the plants of both series were practically identical. It was then decided to take no further separate observations on the deblossomed plants.

DISCUSSION ON THE RESULTS.

In this paper the growth of the plants is described from the autumn of 1925 when they were one year old, until the autumn of 1926. Vigorous root growth went on until late autumn and little production of new roots took place in the winter. In the spring a fairly considerable growth of secondary and tertiary roots took place just as recorded for the spring of the previous year.

Few new primary or main roots were formed during this period and the small number developed seemed to be supplementary in nature, arising mainly on weak crowns or on crowns as yet poorly furnished with main roots. The bulk of the primary roots formed in the previous autumn remained almost completely unfurnished with fine roots until the spring.

At this period of the year from March until midsummer there was a vigorous growth of leaves, flowers and fruit but little root growth. At the beginning of August the commencement of new crown formation began and also of the second post-cropping root system. This growth of roots was slow until mid-August, when they began to be produced vigorously, the growth being maintained until mid-October, the date at which observations recorded here cease. These new main roots originated on old crowns above the old roots and from the bases of the new crowns. The point of origin of most of these new roots, distinctly above the old ones, should again be emphasised in view of its important bearing upon cultural practices. It is interesting to note that up to the date to which these observations carry us, no death of primary, or main roots had yet taken place. The original runner roots and the roots formed in the autumn after planting were by now thick and quite black in appearance, but when this black and dead outer tissue was scraped away a white living core could be seen. Considerable death of secondary and tertiary roots borne by these old primary roots had however taken place.

The chief point of interest is the remarkable consistency with which the sequence of events described for the first season's growth has been followed in the second. The almost dormant period in the winter followed in the spring and early summer by vigorous shoot growth and growth of feeding roots on the primary roots formed in the previous autumn, then the growth of new crowns and primary roots in the late summer and autumn. There were slight modifications due to seasonal differences, e.g., the spring growth of root and shoot commenced earlier in 1926 than in 1925, and also the growth of new crowns and primary roots was not noticeable quite so early in August as in the previous year. This latter may possibly be accounted for by the drought of July.

THE PRACTICAL APPLICATION OF THE RESULTS.

The chief point of practical interest in the observations recorded in this paper are the time of root activity, the main roots being formed in the late summer and autumn, and the origin of these new main roots which have been seen to arise at a higher level on the crowns than any of the older roots. Thus the value of maintaining close contact between soil and crown soon after cropping may again be emphasised. In addition the fact that the plant depends in the following season very largely upon the roots formed in the period extending from shortly after the cropping season until the early winter, indicates the value of assisting this root growth by every possible means. The progress made by the plant in forming strong healthy roots and crowns in the season immediately after cropping is of the utmost importance.

DESCRIPTION OF PLATES.

Plate I.

Fig. 1. Photograph of the crowns and roots of a normal plant at the commencement of the dormant season of its second year. December 1st, 1925. This figure illustrates the points of origin and general appearance of the new roots formed since midsummer, 1925.

Fig. 2. Illustrates the relative quantities of new and old roots from five plants on the same date, viz., December 1st, 1925. There has been a large development of new roots since September, 1925. Cf. Journ. of Pomol., Vol. 5, 3, p. 169. Plate II., Figure 2.

Plate II.

Fig. 1. Condition of a normal plant on January 11th, 1926. Note that many of the new roots are as yet unfurnished with fine lateral roots.

Fig. 2. Condition of a normal plant on April 26th, 1926, the commencement of the blossoming period. Compare with Fig. 1, and note the large increase in fine " feeding " roots and the considerable growth of leaves and flower trusses.

PLATE I.

FIG. 1.

FIG. 2.

PLATE II.

Fig. 1.

Fig. 2.

III.

THE INFLUENCE OF TIME OF PLANTING ON THE DEVELOPMENT OF THE STRAWBERRY WITH A CONSIDERATION OF THE POSSIBLE INFLUENCE OF SOIL AND LOCALITY.

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I.—INTRODUCTION.

IN a previous communication* the writers indicated that an investigation of the effects of the time of planting runners on the subsequent development of the plants was in progress. Preliminary experiments were commenced in the season 1924-1925 and work on a more extensive plan has been carried out during the season 1925-1926. The qualitative results obtained in these experiments are described below.

II.—METHODS AND MATERIAL.

The methods of planting, subsequent cultivations and periodic lifting and examination of batches of plants were the same as those previously described.

In the 1924-25 experiments the development of plants set out in September, October and in the Spring of 1925 was compared qualitatively.

During 1925 runners were planted on the following dates :

August 8th, 1925	200 plants.
September 8th, 1925	200 ,,
October 8th, 1925	150 ,,
December 18th, 1925	150 ,,
March 18th, 1926	150 ,,

In the early experiments the variety employed was Royal Sovereign, except in the case of the October planting, where runners of the variety Sir Joseph Paxton were used. In 1925-26 experiments strong well-rooted runners of a proved strain of Royal Sovereign were used throughout.

III.—RESULTS.

I. 1924-1925 EXPERIMENTS.

The results of experiments in which the development of runners planted in the spring was compared with that of runners planted in early September have already been reported.

* *Journal of Pomology*, Vol. V, 3, pp. 149-169, 1925.

Runners planted on October 20th, 1924, made little root growth before the spring of 1925, and in this respect they resembled the spring-planted runners rather than autumn-planted runners set out in early September. Plants from the three series, viz., September, October and spring-planted were compared on May 11th. Both the later planted series were very inferior to the September series in vigour of both roots and crowns. Furthermore the October planted runners were only very slightly superior to those planted in the spring.

II. 1925-1926 Experiments.

For the sake of convenience in the presentation of records the several series of plants examined will be referred to by the month of planting: thus, runners planted out in August will be referred to as the August series, planted in September—the September series, and so on.

August 8th. August Series. Date of Planting.

The runners planted on this date were well rooted and vigorous, possessing from six to eight well developed leaves. The runner roots were white to yellowish and appeared remarkably well developed and healthy.

September 8th. September Series. Date of Planting.

Runners planted on this date showed a slight amount of root damage.

September 17th. August Series. 5.7 weeks from planting.

The original runner roots had sent out numerous new lateral roots and numerous new white "primary" roots had commenced to develop from the crowns.

October 8th. October Series. Date of Planting.

The initial condition of the runners set out on this date was similar to that of the September planted runners.

October 21st. August Series. 10.6 weeks from planting.

The root systems were generally very vigorous. A large increase in total bulk had occurred, the increase being made up of new lateral roots from the original runner roots and vigorous new primary roots from the crowns. Many of these roots were over six inches in length and well furnished with lateral roots. Still more new roots were appearing from the bases of strong crown buds. The average length of longest new root per plant was 18.9 cms.

All the plants examined showed considerable crown development and whilst all runners were single-crowned when planted, the total crowns on five plants at this date numbered seventeen. The increase was made up of very strong buds, many of which had developed new roots and leaves. One plant showed a well-developed flower truss with the primary flower expanded.

September Series. 6.1 weeks from planting.

The runner roots in this series were much less vigorous than those of the August plants. On the other hand the development of new primary roots was slightly more vigorous in the present series. The average length of the longest new primary root per plant was 22.7 cms., as compared with 18.9 cms. in the August series.

Crown growth was markedly inferior to that of the August plants. Two plants showed one weak lateral crown each and the remainder of the plants were all single crowned. New leaves were still being produced.

December 1st. August Series. 16.3 weeks from planting.

Little apparent change had occurred in the root system since the October examination. In the older runner roots browning of the outer tissues had commenced, indicating the beginning of the development of secondary tissues within the cortex. Growth of new roots appeared to have ceased. The average length of the longest new root per plant was 19.2 cms., as compared with 18.9 at the last examination.

Considerable growth of the crowns had occurred and approximately sixty per cent. of the plants possessed a well-developed flower-truss with the central flower expanded. The average number of crowns per plant, inclusive of strong buds just commencing to put out roots, was 4.4.

September Series. 11.8 weeks from planting.

In total bulk the roots of the plants in this series compared favourably with those of the August plants. Further they appeared whiter and more vigorous and showed no signs of secondary growth in the runner roots.

The development of the crowns was much less vigorous than in the August series. Each plant possessed a single strong main crown with an occasional weak lateral crown in addition.

October Series. 7.6 weeks from planting.

The bulk of the root system was much smaller than in the two preceding series. Numerous new lateral roots had been developed from the damaged runner roots and each plant possessed from ten to fifteen vigorous new "primary" roots for the most part unbranched.

All plants were single crowned and shoot growth generally was slightly inferior to that of the September plants.

December 18th. December Series. Date of planting.

Runners planted on this date had developed numerous new lateral roots and also new primary roots in the confined conditions of the runner bed where they had been "heeled-in." In the process of lifting from the bed and planting out in the field it is impossible to avoid damaging these roots.

January 11th. August Series. 22.3 weeks from planting.

The runner roots showed an advance in secondary growth noted at the last examination and also the longest new primary roots developed in the previous September showed the beginnings of this secondary development. The main feature of the root system as a whole was the commencement of the production of new lateral roots.

By this time the older foliage had decayed and each crown possessed three or four small deep green leaves.

September Series. 17.8 weeks from planting.

The runner roots appeared more vigorous than those of the August plants and had produced more numerous lateral roots. Except for the fact that the majority of the September plants were single crowned in other respects the differences between the two series were not very marked at this date.

October Series. 13.6 weeks from planting.

The runner roots were essentially similar to those of the September plants, but the development of new primary roots was less advanced.

All plants were single crowned and in about half of the plants flower trusses were expanding.

February 17th. August Series. 27.6 weeks from planting. (Plate I., and Plate III., Fig. 1.)

The main runner roots were by this date quite brown owing to the death of the cortical tissues following the development of secondary cork tissues beneath them. The main portions of the new primary roots were also yellow brown. A small number of dead lateral roots on the original runner roots was noted in the centre of the root masses. The feature of the root system as a whole was the prolific development of the numerous small lateral roots which we have previously described as "feeding roots."

Shoot growth had recommenced by this date and new leaves were just beginning to unfold. In point of bulk and general vigour, crown development in these plants compared favourably with that of average two year old plants.

September Series. 23.1 weeks from planting.

The proportion of new roots was smaller than in the case of August plants, but the general appearance of the whole root system was whiter, showing that secondary thickening was less advanced.

The crowns of the September plants were much smaller than those of the August plants and the majority were still single crowned.

October Series. 18.9 weeks from planting.

The runner roots were still white to yellow-brown in the older regions, and the new primary roots formed since planting were for the most part quite white and unbranched. Some new lateral roots had developed from the runner roots but the amount of root development of this type was notably inferior to that in the two earlier planted series.

All the plants were single crowned and crown development was weaker than in the two preceding series.

December Series. 8.7 weeks from planting.

Except for the development of a small number of new lateral roots from the damaged runner roots little apparent change had occurred in the root systems since planting.

Crown development was the least vigorous in this series.

March 16th. August Series. 31.5 weeks from planting.

The death of cortical tissues noted in January had advanced considerably and the main runner roots were now almost black. Lateral roots in these thickened regions were also dark brown, but the central tissues were healthy. A similar colour change had occurred in the older autumn-formed roots, which had also produced abundant fine lateral roots. New primary roots were noted emerging from the bases of the new crowns developed since planting. Generally there was little increase in the total bulk of the root system since the last examination.

Shoot growth was very vigorous, each crown having developed three or four new leaves, the oldest of which were fully expanded. In cases where flower trusses had been partially expanded during the previous autumn further growth of these inflorescences appeared to be arrested.

Cases were observed where roots had been developed from the swollen node of the flower stalks and imperfect flowers with green leaf-like petals were present. A normal flower truss just beginning to expand was usually apparent on each crown.

September Series. 27.2 weeks from planting.

The general appearance of the root systems was similar to that described for the August plants. The points of difference in the present series were the smaller total bulk and the generally lighter colour of the roots.

Vigorous growth of new leaves had occurred as in the August plants and inflorescence development was slightly further advanced.

October Series. 22.8 weeks from planting.

Root development differed from that of the September plants only in bulk and the production of new lateral roots being slightly inferior in both respects.

Little apparent difference in shoot growth between this series and the September series was recorded. All plants were single crowned and possessed from three to five new leaves.

December Series. 12.6 weeks from planting.

New lateral roots had developed from the damaged runner roots and the new primary roots formed in the runner bed before transplanting. No further new primary roots had been produced and the total bulk of the root system was considerably smaller than that of the earlier planted plants.

Crown growth and the development of new leaves differed little from that recorded for the October planted series.

March 18th. Spring Series. Date of planting.

The runners planted out on this date had reached a stage of development in the runner bed similar to that described above for the December plants.

April 27th. August Series. 37.5 weeks from planting. (Plate II.).

Pronounced browning of all the older main roots had occurred. Secondary thickening was also apparent in the majority of the new " primary " roots formed in the autumn of 1925. One or two new primary roots were noted on each of the original main crowns and a further vigorous production of new roots had occurred from the bases of the daughter crowns. These latter roots varied from 2 to 18 cms. in length and their development formed a conspicuous point of difference between the August series and series of plants set out at later dates. In this respect the August plants resembled two year old plants.

Very vigorous production of new leaves and rapid development of the flower trusses had occurred. The average number of crowns per plant was 4.8 and an average plant had produced nine flower trusses. The main flowers and many of the secondary flowers were fully expanded, but the flower development was on the whole less advanced than in the September planted series.

September Series. 33.2 weeks from planting.

The browning of the root system was less marked than in the case of the plants of the August series. The autumn-formed new primary roots showed little trace of the browning observed in the August series. One or two new roots arising from the main crown and a marked advance in the development of fine feeding roots were noted on all plants.

The growth of the crowns was very much inferior to that of the August plants. The average number of crowns per plant was 1.4 and the average number of blossom trusses was 2.8. On the whole flowering was further advanced in this series than in either of the others. In some instances the main flowers had set fruit whilst in many cases tertiary flowers were expanded.

October Series. 28.8 weeks from planting.

The root systems of plants in this series appeared to be equal in bulk with those of the September plants. Secondary development in the older roots was less advanced.

Shoot growth was similar to that of the September plants but less vigorous. The average numbers of crowns and blossom trusses per plant were 1.6 and 1.4 respectively.

December Series. 18.6 weeks from planting.

These plants were essentially similar to the October plants, but less vigorous with respect to both root and crown development. The average figures per plant for crown and flower truss development were 1.0 and 1.8 per plant.

Spring Series. 5.7 weeks from planting.

Browning of the runner roots had taken place, but the characteristic feature of the root systems of plants in this series was the production of very strong lateral roots from the main roots damaged in the process of transplanting. Further new primary roots up to 10 cm. in length had been produced from the crowns on all plants.

The development of leaves was considerably behind that in any other series. The new leaves produced were small and very deep green, with a marked tendency to be highly pigmented especially in the petioles which were in many instances bright red. All plants were single crowned and a blossom truss was beginning to make its appearance on each plant.

Note :—At a later date all blossoms were removed from the plants in this series.

June 7th. August Series. 43.5 weeks from planting.

There appeared to be little increase in the development of the root systems since the last examination. A very pronounced advance in secondary thickening of the roots had occurred so that the main portions of the runner roots were now quite black and the bulk of the remaining roots uniformly brown. A few new roots up to 8 cms. in length, developed in the spring from the young crowns, were now well furnished with fine feeding roots.

Shoot growth had advanced very considerably and the large bulk of foliage strengthened the resemblance to two-year-old plants previously noted. In most plants flowering was over and the primary fruits were fully developed and commencing to change colour. Stolon formation had commenced and the first runners had developed roots in the most advanced instances. The average length of the four best developed stolons per plant was 4.5 cms.

On the whole the condition of the fruit and the amount of runner formation was slightly behind that in the September series.

September Series. 38.9 weeks from planting.

Secondary thickening in the roots was less advanced in this series so that the root systems as a whole appeared more vigorous than those of the August plants. A few new primary roots developed in the spring were by this date well furnished with fine lateral roots.

The growth of leaves and the development of the fruit was similar to that in the August series, but since most plants were single crowned the total bulk of foliage and fruit was considerably less. The primary fruits had attained a half-ripe condition and runner formation was more vigorous than that in the August series. The average length of the four strongest stolons per plant was approximately 50 cms.

October Series. 34.7 weeks from planting.

December Series. 24.5 weeks from planting.

There were few apparent differences between the root systems of plants from these two series and both were only slightly inferior to the September plants.

The character of the shoot growth was similar to that of the September plants, the difference being one of smaller total bulk in the later series. Runner formation was less vigorous. In the October plants the average length of the four longest stolons per plant was 34 cms. as compared with 32 cms. in the December series.

Spring Series. 11.6 weeks from planting.

The root systems of these plants were markedly different from those of any other series. Vigorous growth of new lateral roots had occurred, so that the whole root mass presented a much fresher appearance than that of earlier planted runners. The new primary roots developed since planting were much stronger than those noted in other series and resembled the roots formed in the autumn on the plants in the earlier series.

Shoot growth was the least vigorous of any series. Runners were fewer and shorter, the average length of the two longest runners per plant being 25 cms.

June 12th to July 7th.

The first picking of ripe fruit was made on this date and it is a point of interest that in this first picking the amount of fruit obtained from the August series was approximately half that picked on an equal number of September plants, and also less than the amounts obtained from the October and December planted series. In the second picking, June 16th, the yield of fruit from the August series was double that from the September series and in all subsequent pickings, which were made at intervals of three days up to July 7th, greatest yields

were recorded on the August plants, followed by the other three series in the order of planting.

The total crop obtained from the August series was approximately three-and-one-half times that obtained from the September plants. There was little significant difference in yield between the September and October series, whilst the crop from the December plants was one-eighth of that from the August series.

July 19th. August Series. 49.5 weeks from planting.

The original runner roots and the main portions of the primary roots developed in the autumn had increased in thickness and the older tissues had decayed. These roots were still furnished with active lateral roots, but secondary thickening had also advanced in these roots since the last examination. The main point of interest was the commencement of the development of numerous new roots from the bases of the younger crowns.

The older leaves were by this time quite brittle and many were breaking down. The strawberry leaf spot fungus (*Mycosphaerella fragariæ*) was observed to be more prevalent on the older foliage in this series than on the foliage in any other plants. New leaves were being produced from the main crowns and also from new daughter crowns. The latter were developing in all the main crowns and usually two were observed one on either side of the old inflorescence stalks.

September Series. 44.9 weeks from planting.

Secondary thickening of the older roots was well advanced and new roots were beginning to appear from the bases of new crown growths.*

New leaves and daughter crowns were developing as in the case of the August plants.

October Series. 40.7 weeks from planting.

December Series. 30.5 weeks from planting.

Except for the smaller bulk of the plants in the present two series, the same features of root and crown development described above were recorded.

Spring Series. 17.6 weeks from planting.

The root systems of plants of this series were generally more vigorous in appearance than those of earlier planted series. Secondary thickening was less advanced and more numerous new roots were developed from the new crown growth.

The daughter crowns had developed more rapidly than those of either of the earlier series.

* Cf. *Journ. Pomology*, Vol. V., 3, pp. 156-7, notes under July 20th.

August 18th. August Series. 53.8 weeks from planting.

All roots, except those formed during the spring and early summer, were now quite brown and decay of numerous finer "feeding roots" had occurred. The main roots were much thickened and a further advance in the production of new primary roots from the bases of the new crowns was observed.

The development of the new daughter crowns had advanced rapidly with a consequent large increase in the amount of new foliage. The average number of main crowns per plant was 4.0 and an additional number of daughter crowns averaging six per plant was recorded.

September Series. 39.2 weeks from planting.

Root and crown development was essentially similar to that recorded for the August plants. The development of daughter crowns was slightly stronger in the plants of the present series and many of the new crowns had developed numerous new roots.

October Series. 45.0 weeks from planting.

December Series. 34.8 weeks from planting.

Except that the December plants were slightly smaller than earlier planted plants there appeared to be few significant differences between the plants in the three series set out in September, October and December.

Spring Series. 23.5 weeks from planting.

The roots still appeared more vigorous than those of plants of the earlier series. Less death of fine feeding roots had taken place and the development of new roots was more prolific.

The development of daughter crowns was more vigorous than that observed in the September series.

September 14th. August Series. 57.7 weeks from planting. (Plate III., Fig. 2.)

The conspicuous feature of the root systems on this date was the vigorous production of new roots especially from the daughter crowns. Many of these new roots were freely branched.

Crown development with the production of new foliage had advanced rapidly and an average plant now possessed ten crowns, all of which had produced well developed roots.

September Series. 53.1 weeks from planting.

Plants in this series differed only in bulk from those of the August series. An average plant was now represented by seven well developed crowns.

October Series. 48.8 weeks from planting.

December Series. 38.6 weeks from planting.

In general appearance these plants compared favourably with those of the September series, but were smaller in bulk.

Spring Series. 29.9 weeks from planting.

The older roots showed a larger proportion of vigorous lateral roots and a greater development of new roots from the daughter crowns. The average number of new crowns per plant was seven, and the foliage appeared more vigorous than that of any other series.

October 21st. August Series.

By this date considerable further development of new primary roots had taken place from the daughter crowns developed since the cropping period. The older roots had thickened and flaking off of the dead outer tissues was very pronounced.

Crown development had been extensive and an average plant now possessed five main crowns and eight young daughter crowns.

September Series.

The development of new roots appeared more vigorous than in the August series. The number and length of new primary roots was greater in proportion to the crowns.

The average number of crowns per plant was nine, this figure including new daughter crowns developed since the cropping period. Generally speaking the plants in this series were slightly inferior to the August plants.

October Series and December Series.

Neither of the above series differed greatly from the September Series. There was still a small inferiority in bulk, but detailed observations were not made on plants from either series on this date.

Spring Series.

The most vigorous production of new roots had occurred in plants of this series and they compared favourably with plants from the September series as regards bulk.

New crown growth had been rapid and each plant now possessed on the average eight well developed crowns.

By this date the plants in the several series showed a tendency towards equality of vigour and it was difficult to distinguish between the September, October, December and Spring plants in the field.

Discussion of the Results.

The preliminary experiments carried out in 1924-1925 indicated that by delaying planting until late in the autumn the subsequent development of the plants was materially affected. It has been shown that during late summer and autumn a marked development of the roots normally takes place. The plant depends largely on these autumn formed roots for its further development in the spring. If planting be delayed too long adequate provision of new roots cannot be made before the dormant season sets in, consequently the general vigour of the plant in the following growing season is impaired. The results obtained showed that runners planted in late October were in no way superior to runners set out in the spring when plants of the two series were compared in May. Furthermore, the plants of both series were not sufficiently vigorous to carry a crop and it was necessary to remove the weak flowers produced in order to ensure a crop in the second season.

In the second series of experiments the general results obtained emphasise very strongly the extreme importance of the late summer and autumn phase of vigorous root development. The formation of new roots was greatest in plants set out on August 8th, 1925, and proportionately less in the successive series. The ultimate result of this activity was reflected in the performance of plants of the several series in the spring and summer of 1926. From the outset, plants of the August series were the most vigorous, comparing favourably with normal two-year-old plants, and bearing a crop approximately four times heavier than that borne by plants set out in September. The longer planting-out was delayed the greater was the reduction in the vigour and cropping capacity of the resulting plants. Plants of the December series were on the whole less vigorous than plants set out in the spring and deblossomed in May.

When an early runner plant has established its first roots it rapidly reaches a stage of development when it is fully capable of supporting itself independently of the parent plant. This stage was reached at Long Ashton in 1925, towards the end of July. Subsequent development, as our results show, depends to a great extent on the time elapsing between the attainment of this stage and the transplanting of the runners to permanent quarters. The longer the runners remain *in situ* the less vigorous will be the resulting plants. The explanation of this fact would appear to be as follows. In the crowded conditions of the strawberry bed development is retarded by competition with both the parent plants and other runners. In the second place, the longer the runners remain in the old bed the greater will be the damage to the developing root system when the plants are eventually removed. Finally, if the runners are heeled in before planting they suffer a further check in the development of the root system.

In the case of the August series the runners were planted in the new bed before the period of growth of new crowns had ceased. These plants became

sufficiently well established to continue crown growth with the result that by the time the dormant season was reached three or four new crowns had developed on each plant. The production of partially developed flower trusses on these plants is probably a consequence of the renewed active growth in the latter part of August and continued during September. The runners used were all "first runners" and on removal and "heeling-in" each plant possessed a single strong main crown. In the strawberry plant blossom bud differentiation depends on the stage of development of the crown and therefore takes place at a considerably earlier date in the well developed first runner than in runners formed subsequently. Given favourable conditions for growth the terminal bud of such a runner will expand and the young flower truss develops. In addition, axillary buds below the main growing point also develop and give rise to daughter crowns. As growth slows down the rudiments of new flower trusses are developed within each of these new crowns and in the terminal bud of the main crown. This late growth of the shoot is only possible if an adequate development of the root system occurs before the close of the normal growth period of the crowns. The new crowns developed in such cases produce some new roots during the late autumn, but a further development of new primary roots occurs in the spring. In this respect plants of the August series differed from those planted in September and resembled more closely the two year old plants the root development of which has been described in the second paper of this series.

The observations made on the September planted series agree very closely with those made in the season 1924-1925, fully described in a previous paper (*loc. cit.* p. 160). Except that root and shoot growth ceased at an earlier date and also recommenced some three weeks earlier in the spring of 1926 the results obtained confirm very clearly those obtained in the previous season. The main points of difference between plants of the September series and those planted in October were the less vigorous production of new roots in the autumn and the consequent smaller bulk of the resulting mature plants in the latter series.

The plants of the December series differed little in their subsequent development from those planted in the spring. The development of the root systems followed a similar course in the two series and the spring planted series appeared the more vigorous in the late summer. This slight superiority in vigour may be accounted for by the fact that the spring plants were deblossomed, a procedure previously shown to favour vegetative growth (*loc cit.*, p. 161).

IV.—THE PRACTICAL ASPECT OF VARIATION IN THE TIME OF PLANTING.

It has been seen from the above account that in each of two seasons the value of early planting at Long Ashton was clearly demonstrated. The crop obtained in 1926 from plants planted in early August of 1925 was about at the rate of two

tons per acre. This may seem a high figure, but equally good results have been obtained in commercial plantations, and in 1926 one of the writers saw a patch of maiden plants of 3 acres in extent in Hampshire from which a crop of over 2 tons to the acre was obtained. It has been stated above that progressively smaller crops were obtained from the later dates of planting, but the most remarkable difference was between the runners planted in August and September, the former cropping over three times more heavily than the latter. It must not be assumed that equally good results would be obtained by early planting in all districts. Two conditions at least are essential for success; first to obtain early rooted runners, and secondly the right weather conditions for planting and subsequent to planting. The former difficulty might be overcome by buying runners from another district, but in the second case it is obviously useless to plant in a drought or if conditions subsequent to planting are likely to be such that the runners will dry out and fail to become established. The writers would, however, like to emphasise the great value of planting runners at the earliest possible date compatible with local conditions. The earlier the runners are in their permanent quarters the more likely are they to make strong crowns since they are able to make full use of the latter portion of the normal period of shoot development. This increased crown development further ensures vigorous new root formation and consequently less losses of plants will be experienced.

THE NORMAL DEVELOPMENT OF PLANTS IN NORFOLK SEASON 1925-26.

I.—INTRODUCTION.

THE normal development of the strawberry plants set out in early September at Long Ashton has been described in detail for the season, 1924-25 and 1925-26. In order to ascertain whether difference of locality would have any effect on the sequence of events, 150 runners of Royal Sovereign were planted out in September, 1925, at a fruit farm near Norwich.* In this district the average annual rainfall is considerably less than at Long Ashton, the average rainfall at Long Ashton being 34.88 inches and at Norwich 26.48 inches. In addition the soil of the field in which the runners were planted was of a lighter nature than that at Long Ashton.

* The work was carried on at the Hoveton Fruit Farm through the courtesy of Mr. T. R. C. Blofeld. Mr. A. C. Drake was responsible for the work entailed in raising and washing out the plants and the writers take the opportunity here of expressing their appreciation of his co-operation.

II.—METHODS.

Batches of five of these plants were lifted at intervals and despatched to Long Ashton for examination. These plants should throughout be compared with those planted in September, 1925 at Long Ashton. The plants did not in both cases originally come from the same source, but two strains of similar vigour and which had been grown at Long Ashton for a number of years were selected.

October 26th, 1925. 6.3 weeks from planting.

At this date more vigorous root growth had taken place than on the runners planted at Long Ashton at the same date. The runner roots had produced a greater quantity of lateral roots and also there was a larger number of new primary roots. The average length of the longest new primary root per plant was 12.8 cm.

December 1st, 1925. 11.4 weeks from planting.

The root growth was more vigorous than on either the September or even the August planted runners at Long Ashton. The longest new primary roots averaged 18.5 cm.

The crowns were vigorous but as yet few daughter crowns were present. The whole plants were more vigorous than those planted at Long Ashton in September.

January 26th, 1926. 19.4 weeks from planting.

Very little root growth had taken place since early December. The marked fibrous nature of the root systems as compared with the Long Ashton plants was again noted.

March 19th, 1926. 27 weeks from planting.

The runner roots were by this date becoming black. Practically no new root growth was recorded. Most of the plants had only a single crown, in this resembling the Long Ashton September-planted series, and not the August-planted. The shoot growth was definitely not so forward as at Long Ashton.

April 30th, 1926. 33 weeks from planting.

At this date the plants seemed to be equal in vigour to the Long Ashton plants, but not so forward in growth, the primary blossom not yet having expanded.

June 11th, 1926. 39 weeks from planting.

The plants seemed to be very comparable with the Long Ashton September-planted series.

July 23rd, 1926. 45 weeks from planting.

The plants were not so forward in new crown or root development as the Long Ashton plants, only a few new crowns or roots just being visible. There were only very few new leaves expanding on the old crowns.

August 16th, 1926. 48.3 weeks from planting.

The growth of new primary roots was much more marked than on any of the Long Ashton plants. Few new daughter crowns could yet be seen.

October 2nd, 1926. 55.1 weeks from planting.

Vigorous new root growth had taken place since mid-August. The number of new daughter crowns was much less than that on the Long Ashton September-planted series.

DISCUSSION.

The most striking difference between the runners planted in Norfolk and those at Long Ashton was the more vigorous growth of roots made by the former in the autumn after planting. The more vigorous growth of the lateral roots on the old runner roots was especially noticeable. This may possibly be explained by the lighter nature of the soil in which the runners were planted in Norfolk. Growth of the Norfolk plants did not commence so early in 1926. In the Autumn after cropping fewer new daughter crowns were formed than on comparable plants set out at Long Ashton. The annual sequence of growth, however, has been seen to be exactly the same as that in the Long Ashton district—viz., a vigorous growth of new primary roots and of lateral roots on the runner roots in the three months after planting, followed by a dormant period. This was broken by a slight growth of fibrous roots in the spring and a vigorous growth of foliage and flowers in the spring and summer. Soon after the crop had been picked a vigorous growth of new primary roots and of new daughter crowns commenced, the former being prolonged after the crown growth had ceased.

It would seem that the normal growth sequence will be followed in all localities in this country, but that there may be slight seasonal variations and also variations due to locality. These variations are not changes in the sequence of growth but in the time at which phases of growth are initiated or terminated, or, again, in the volume of either the primary or finer roots or of the amount of shoot growth. In other words, there are definite periods for root or shoot growth and these are approximately the same when season and locality are variables, but the volume and nature of the root formed and of the shoot growth may vary somewhat.

PLATE I.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

PLATE II.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

PLATE III.

FIG. 1.

FIG. 2.

DESCRIPTION OF PLATES.

Plate I.

Figs. 1 to 4. Illustrate the condition on February 17th, 1926, of plants set out respectively in August, September, October and December, 1925. There is a clear gradation in the vigour of the plants, the August plant having the strongest branched crown and the largest root system.

Plate II.

Figs. 1 to 4. Illustrate the condition on April 27th, 1926, of typical plants of the August, September, December and Spring Series respectively.

Note (1) The general superiority of the August plants.

(2) The general gradation in vigour previously observed is still maintained.

(3) The development of a few new primary roots in the Spring planted runner.

Plate III.

Fig. 1. This photograph taken on February 17th, 1926, shows the new roots produced since planting by five plants each of the August, September, October and December series respectively.

Fig. 2. This illustration made on September 14th, 1926, shows the relative proportions of new and old roots from five plants of each series set out in August, September, October and December, 1925, and in the Spring of 1926.

IV.

THE INFLUENCE OF SOME CULTURAL PRACTICES ON THE NORMAL DEVELOPMENT OF THE STRAWBERRY PLANT.

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I.—INTRODUCTION.

In the general plan of investigations drawn up in the first communication on the subject of Strawberry Root and Shoot Development it was stated that the effect of various methods of planting and of cultivation were to be investigated. A progress report on the work appeared in the Long Ashton Annual Report for 1925. In the course of these experiments the desirability of a more precise knowledge of the distribution of the roots in the soil became apparent. Work on this subject was therefore carried out and the results are described here. In the present paper further results of these investigations are described.

II.—METHODS OF PLANTING.

The different methods investigated were :

(i.) Deep planting.
(ii.) Shallow planting.
(iii.) Trimming the roots before planting.

Deep Planting.

The runners were planted deep enough just to cover the crown completely with soil. In the normal series the soil level was about mid-way up the crown.

Shallow Planting.

The runners were planted, so that the whole crown was above soil level. Thus the two extremes were taken in order to make the distinction between them and the normal depth of planting quite clear.

Root Trimming.

About one-third to one-half of the runner roots were cut off before planting. This is the usual practice in certain districts and in Canadian practice the runner roots are generally trimmed before planting. In view of this the experiment was carried out to ascertain whether any value attached to the practice if carried out under local conditions.

The plants were raised at intervals and examined in a similar way for comparison with plants in the "normal" series. No quantitative data were obtained. In September, 1925, a further series of runners was set out and examined at intervals during the following twelve months.

METHODS OF PLANTING. RESULTS 1924–26.

(i.) *Deep Planting.* (Plate I., Fig. 1, c.).

At seven weeks from planting the new main roots were rather fewer in number, but just as many lateral roots were being produced on the original runner roots as in the normal plants. The amount of dead roots was noticeable but on the whole the root system was not much inferior to that of plants which had been planted at the normal depth. At a year from the date of planting the vigour of the plant did not differ from that of one in the "normal" series. The rhizome or underground portion was very long, and consequently the point of origin of the new roots appeared to be about two inches above the old ones, as compared with one inch on the normal plants.

(ii.) *Shallow Planting.* (Plate I., Figs. 1, d and 2, b.).

At seven weeks from planting the original runner roots were noticeably well furnished with laterals; in fact they compared favourably with the normal plants in theis respect. The new primary roots were fewer in number than on the normal plants, and had their origin at the same nodes as the older roots. Many of these new primary roots had not developed normally, their growth having been arrested before they reached the moist environment of the soil. The effect of the shallow planting was not very serious at this date. By November 9th, the new primary roots which had developed were only at the same stage reached by those of the normal plants on October 16th, in that they were as yet not well furnished with laterals. It was noticed that the exposed portion of the new primary roots was coloured with a red pigment. A year later as a result of cultivation the position of the main crown in relation to the soil was not well maintained, and consequently the difference in vigour between the shallow planted and normal plants was not great at this date. But on the whole the root system was not so vigorous as that of a plant set at the normal depth. When it happened that the new roots had their origin at some distance from the soil level (this frequently occurred on one side of the plant only), it was noticed that they were red in colour and that the tips had died.

(iii.) *Roots Trimmed.* (Plate I., Fig. 1b.).

In the seven weeks following planting lateral roots were abundantly produced near the region of the cut ends of the runner roots. This is well illustrated in Plate I., Fig. 1b. The new primary roots seemed to be more abundant than on the normal plants, and to have their origin mostly about the old roots. In

addition, they were stronger and better furnished with laterals, and in some cases were longer than the old primary roots of a normal plant, the length of the longest being 16 cm. The bulk of the root system was equal to, if not greater than, that of a normal plant whose crown was of the same size—hence the volume of *new* roots was greater, the increase being both in laterals on the cut runner roots and in new primaries with their laterals. A year later the plants were in no way superior in vigour to those the roots of which had not been trimmed. The vigorous roots which had been produced at the cut ends of the runner roots were still well furnished with living laterals.

The observations made on the series of runners planted in September, 1925, confirmed in practically every detail those made in the previous season.

DISCUSSION.

The effect of deep planting was to cause a certain amount of root death, but the ultimate vigour of the plants was not much impaired under the local conditions. The increase in length of the main crown as compared with that of plants set at the normal depth was very noticeable. The effect of shallow planting was more detrimental, resulting in the death of some of the new primary roots, which were unable to reach the moist soil before succumbing to drought. The vigour of the plant obtained in the following season was also impaired. The trimming of the runner roots before planting did not impair or enhance the ultimate vigour of the plants. The treatment resulted in the copious production of lateral roots near the cut ends of the main runner roots, and six weeks after planting the bulk of the roots was the same as that of a normal plant and hence the growth of the new roots had been greater. Root trimming may possibily be advantageous in cases where the runner roots are abnormally long in which case it would prevent bunching up the roots in the course of planting.

III.—CULTURAL TREATMENTS.

The above discussion leads up to the subject of cultural treatments. The bad results of shallow planting have been described and it would seem possible that exposure of the crowns of established plants at the time when new roots are actively growing would be very detrimental, and conversely, a slight moulding up of the plants may prove advantageous.

In September, 1924 and 1925, a number of runners were planted in units of fifty to examine the effect of

(i.) Earthing up the plants.
(ii.) Drawing the earth away from the crowns.
(iii.) Damage to the crowns at various seasons.
(iv.) Damage to the roots.
(v.) Water-logging.

The plants were earthed up or, conversely, soil was scraped away from the crowns, after cropping, viz., at the end of July. In the former case the soil was drawn well towards the crowns making good the contact between soil and crown and in the latter case the soil was removed until the crowns were exposed right down to the point where the uppermost roots could be seen to have their origin.

RESULTS OF CULTURAL TREATMENTS.

Stated briefly the result of earthing up the plants in August was to increase the vigour of the plants, the new crowns producing roots more freely and thus attaining greater vigour. The effect of drawing soil away from the plants and exposing the crowns was a decrease in the vigour of the plants compared with the controls or untreated plants. Several of the new main roots formed in the autumn failed to reach the soil, were pink in colour and died from the tip upwards. As a result of this the new crowns had abnormally small root systems. Correlated with this was the small size of the leaves produced in the following season. The leaves were quite normal in shape and not in any way deformed except that perhaps the length of the petiole was short when compared with the size of the lamina. Thus we have a small leaf blade with a more than proportionately small leaf stalk. In the course of keeping a number of strawberry plants under close observation it was noticed that several of the plants produced leaves of this type and invariably associated with this condition was a raised or exposed crown.

IV.—THE EFFECT OF MECHANICAL DAMAGE.

(a) DAMAGE TO THE CROWNS.

In view of its possible bearing upon " Red Plant " or other abnormal forms of growth of the strawberry plant, the effect of artificial damage to the crown and to the roots was investigated. In the course of making regular detailed observations on strawberry plants, it was noticed in the Spring that certain plants occurred which had a distinctive type of abnormal foliage. Illustrations of this condition have been given in the Long Ashton Annual Report for 1925.* The leaves were smaller than usual, of a thinner texture than normal leaves, and the petiole was less hairy, longer and thinner in proportion to the leaflets than was usually the case. In addition the leaf blades were abnormal in shape, the serrations coarse and fewer than usual. Some of these plants were carefully dug up and examined, and it was found that the main crown had been severed and several weak buds below the cut had developed, giving weak

* Ann. Rpt. Univ. Bristol Agric. Horti. Res. Sta., Long Ashton, p. 53. 1925.

lateral crowns with the type of foliage described above. This condition seems to be analogous with "temporary reversion" in the black currant. The latter condition is produced by cutting a bush hard back and causing weak buds to break. These produce shoots bearing an abnormal type of leaf, very similar to the "reverted" leaf. The condition of the strawberry plants above described was in all probability due to hoe damage, in which the top of the crown had been completely severed. In order to confirm this view in 1925 the crowns of a number of plants were cut at ground level. A condition identical with that described above was produced. Observations were made on these plants throughout the season, and it was noticed that eventually a very dense form of plant was produced, having leaves of the normal shape and size. This was due to the growth of a relatively large number of crowns very close to one another.

In 1926 the work was repeated both in the field and with plants grown under more closely controlled conditions in pots. In the field experiments damage was inflicted on four dates between the spring and late summer. On each date, twenty-five of the plants had the crowns cut off at soil level and from twenty-five others the main growing point was removed as completely as possibly by cutting out the centre of the crown with a scalpel. By the former method identical results with those of the previous season were obtained but it was found that the operation must be performed when the plant was growing vigorously and that the cutting must be severe, viz., sufficiently low to remove all the stronger or better developed lateral buds. By the second method of crown damage, i.e., removal of the centre of the crown the results described above were not obtained—lateral buds grew out but produced leaves which were quite normal in shape and size. An explanation of this can be seen in the foregoing remarks on the effect of the complete removal of crowns at soil level.

It is considered of value to draw attention to this form of "small leaf" since certain features are sometimes confused with "Red Plant" symptoms in diagnosing that condition. It often happens that only one or two small crowns developing from weak lateral buds on a plant produce leaves of this type and continued observations will show that they eventually produce leaves of the normal size and shape.

(b) THE EFFECT OF DAMAGE TO THE ROOTS.

Three hundred runners of the variety Royal Sovereign were planted out in September, 1925, as material for this work.

The roots were damaged by cutting around the plant with a thin sharp knife blade at a distance of about two inches from the crown. On raising some of these plants it was found that severe damage to the root had been effected to a depth of about three or four inches. These operations were carried out on four occasions during the season 1926 between the Spring and August.

Damage to the roots in the spring or summer resulted in a decrease in vigour of the plants compared with plants not treated in this way. The size of the leaves was also smaller and they approached the condition of those borne on plants with raised or exposed crowns described above.

(c) THE EFFECT OF WATER-LOGGING.

In order to investigate the effect of water-logging troughs were made which were water-tight and of such a size as to contain single rows each of ten plants in 6-inch pots. Two varieties were used—" Royal Sovereign " and " Stirling Castle." The troughs were kept filled with water to such a level that the pots stood to a depth of about three or four inches in water.

The plants were kept in a water-logged condition throughout the spring and summer. The most striking effect was upon the size and colour of the leaves. After the plants had been subjected to this treatment for some little time the new leaves produced never attained the normal size but remained extremely small resembling in size and shape those produced by extreme exposure of the crowns. The older leaves assumed autumn tints very early in the season and died abnormally soon. As a result of the death of the old leaves and of a large portion of the root system the new crowns were very weak and as described above produced abnormally small leaves (Plate II.) This condition, not always so marked, can be seen in the field in places where the plants are subject to water-logging which results in the death of a portion of the root system.

V.—SOME FORMS OF STRAWBERRY " SMALL-LEAF."

" Small-leaf " is a term which has become current of recent years and is used in speaking of abnormal, weak plants, the chief characteristic of which is the production of weak crowns and under-sized leaves. It will be seen from the account of the above experiments that some causes of the production of " small-leaf," apart from pure weakness of stock, may be accounted for. Small leaves were produced by

(1) Exposure of the crowns.
(2) Water-logging.
(3) Artificial damage to the roots.
(4) Damage to the crowns.

It will be seen that the effects of 1, 2, and 3 are essentially the same, i.e., the reduction of the root system. In (1) the establishment of new roots is prevented. In (2) the old roots are killed and the new ones do not develop to their full extent. In (3) a proportion of the roots is destroyed, but the plant eventually regains its normal condition as soon as a new supply of roots has been formed.

All three of these conditions, which are essentially the same, may occur in the field and account for, at any rate some of the "small leaf" which is so prevalent. Both (1) and (3) may be brought about by cultivation, the plants sometimes being badly exposed and the roots damaged, especially where the weeds have got out of hand and heroic measures are called for.

"Small-leaf" due to water-logging has been recognised and can be remedied, at any rate partially, by making furrows between the rows of strawberry plants in the autumn in places where water lies on the land in the winter. This is of course the usual practice.

"Small-leaf" due to damage to crowns may, as stated above, be due to hoe damage in the spring. This is not extensively met with, and, as pointed out above, attention is only drawn to the condition on account of the possibility of confusion with "Red Plant" symptoms.

VI.—ROOT DISTRIBUTION IN THE SOIL.

It will have been seen from the discussion of the effect of damage to the roots and the importance of not disturbing the new roots formed in the autumn after cropping, how desirable is some definite information on the distribution of the roots in the soil. It has long been known that the strawberry is a surface rooting plant but any more precise information, as far as the present writers are aware, has never been obtained. It will be seen from the observations previously recorded that the range of the roots does not extend very far beyond the outermost leaves in the summer. It will be remembered that in raising the plants for examination a cube of soil the upper side of which extended slightly beyond the outermost leaves was dug up and that in this process extremely little root was lost. Hence the conclusion is reached that very few roots extend beyond the outermost leaves. In the work now being described, the depth to which the roots penetrate the soil and the proportion of them at successive levels was the subject under investigation. The process was as follows. The plant was raised with a cube of soil in a large box which was sunk around the plant by digging away the soil at the edges. The top or aerial portion of the plant was previously completely removed by cutting it off at ground level. The box was finally in such a position that the bottom was flush with the soil level. The box had been made in such a way that successive layers of three inches could be removed at a time, fifteen inches being the total depth. The top three inches was again sub-divided in three layers of one inch. The box having been raised full of soil, each of the successive layers of soil was removed by means of a wire cutter, placed in a fine sieve, and all the soil washed away, the roots being retained. These roots were collected and the dry weight obtained. A number of two-year-old plants were treated in this way in the dormant season and yielded the following figures :—

1. Distribution of the Roots of a Normal Strawberry Plant in a medium loam soil at Long Ashton.

The figures are based on dry weight determinations and are expressed as percentages of the total dry weight of the root system.

		%	
Surface to 3 inches	..	73.11	90.06% of the total root system was present in the uppermost six inches of the soil.
3 inches to 6 ,,	..	16.95	
6 ,, 9 ,,	..	2.32	
9 ,, 13 ,,	..	4.86	
13 ,, 16 ,,	..	2.76	

2. Distribution of the Roots in the Upper six inches of the soil.

		%
Surface to 1 inch	..	25.7
1 inch to 2 inches	..	21.6
2 ,, 3 ,,	..	26.0
3 ,, 6 ,,	..	16.7

VII.—THE PRACTICAL SIGNIFICANCE OF THESE OBSERVATIONS.

It has been seen that a distinction has been made between two definite types of small-leaf. The first being the result of crown damage and the second the result of damage to roots or to the prevention of the formation of a normal vigorous root system. The first type is merely alluded to in order to point out the liability of confusing it with true "red plant" symptoms. The second type results in a material reduction of crop and the point of immediate interest is how to prevent its occurrence. It has been seen that the second type of "small leaf" described may be due to (1) damage to roots, (2) exposed crowns, (3) water-logging. The remedy, or rather the means of preventing the occurence, is obvious. In the case of (1) by more careful cultivation, (2) by a slight moulding up of the plants when necessary (3) by drainage, e.g., by taking furrows between the rows of plants in the autumn. Consideration will show that there can be, in all probability, no satisfactory remedy for plants which have reached this "'small-leaf" condition. Our investigations have shown the prime importance of the late summer and autumn phase of root development. It has also been demonstrated that the amount of root growth which occurs during this period is dependent on early, vigorous development of the crowns. The much impaired vigour of the crowns and foliage of a typical "small-leaf" plant will of necessity be reflected in weak development of the new roots and consequently a still further reduction in general vigour will be apparent in the following growing season. It must not be assumed that all cases of "small-leaf" are due to the above causes; it has recently been shown that there is at least

another factor to be considered, viz., the strawberry aphis. The observations recorded on the distribution of the roots in the soil further emphasise the surface rooting habit of the strawberry and the need for careful cultivation in the immediate proximity of the plants.

DESCRIPTION OF PLATES.

Plate I. Methods of Planting.

Fig. 1. Condition on January 11th, 1926, of four plants set out in September, 1925.

(*a*) Planted at normal depth.
(*b*) Roots trimmed before planting.
(*c*) Deep planted.
(*d*) Shallow planted.

Fig. 2. Typical plants of the normal series (*a*) and the shallow planted series (*b*) on April 27th, 1926.

Note the weaker crown and flower truss of the latter and also the less vigorous root system.

Plate II. Effect of Water-Logging.

Fig. 1. A normal pot plant (*a*) is compared with one subjected to the water-logging treatment (*b*) described in the text.

Note the normal shape but small size of the leaves produced on the latter plant.

Fig. 2. A surface aspect of the above plants.

Plate III. Root Distribution.

Fig. 1. Illustrates the relative quantities of roots present in successive layers of the soil at the depths indicated.

Fig. 2. Shows the relative distribution of the roots in the upper six inches of the soil.

PLATE I.

a. *b.* *c.* *d.*

FIG. 1.

a. *b.*

FIG. 2.

PLATE II.

Fig. 1.

Fig. 2.

PLATE III.

FIG. 1.

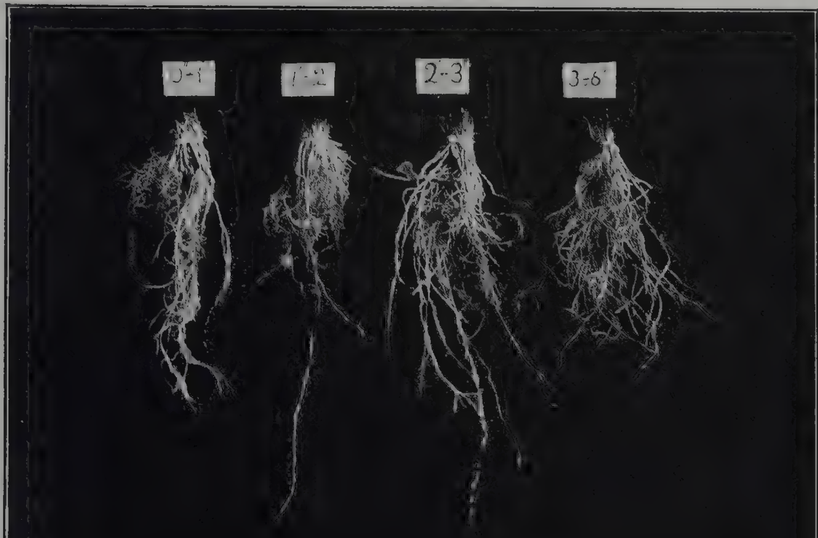

FIG. 2.

A REPORT OF CERTAIN DISEASES OF THE APPLE IN THE NELSON DISTRICT, N.Z., 1925-26.

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INTRODUCTION.

In the summer of 1924, several orchardists situated on the hill land at Braeburn and Umukuri suffered considerable loss in their apple crop through surface pitting and through deeper-seated damage to the flesh in some varieties of apples. In the season which has just closed, injury of a similar nature, but much greater in extent, has occurred in the same orchards which were affected in the 1923-24 season. In addition, a number of other orchards in different parts of the Moutere Hills have been affected to a small or large extent.

PART I.—DESCRIPTION OF THE DISEASES.

(1) Characteristics.

The damage done to the apple crop was revealed in the case of the Sturmer variety by the occurrence of small darker coloured areas on the surface of the apple. These appeared when the apples were as large as walnuts. They were soft to the touch and a small drop of clear liquid was frequently found on the surface at each affected point. At this stage cell growth apparently stopped at the affected parts, resulting a few weeks later in hemispherical pitting at the surface which was such a characteristic symptom of injury in the Sturmer variety.

In certain varieties serious malformation of the apples sometimes occurred, the surface being thrown into irregular elevations and depressions. Frequently there was no external sign of damage to the apple ; but on cutting, corky areas brown or dark brown in colour were noticeable in the flesh. In other cases corky areas and defects in the tissue of the apple did not occur, but the cells surrounding the core of the apple were brown. In certain varieties all stages of damage were seen, from a very small amount of brown tissue, immediately surrounding the core, to severe pitting of the flesh causing an unsightly appearance of the apple.

* Photos. by Miss H. B. Kirby. Mechanical Analyses by Mr. L. Bishop.

In those cases where browning of the tissue alone occurred, it was generally confined to the cells surrounding the core within the circle formed by the ten fibro-vascular bundles. Corky areas and gaps in the flesh were frequently associated with the fibro-vascular bundles. In cases of severe injury where the growth of the apple had been seriously affected, brown corky areas occurred, not only in immediate contact with the main fibro-vascular bundles, but also at irregular intervals in the whole tissue of the apple. In particular, groups of cells immediately under the skin of the apple were affected, resulting in typical hemispherical pitting of the surface.

In the case of Jonathans it was noticed that the extent of damage did not increase during the autumn months. In the month of May many apples were examined in an affected orchard where no picking had been made. The type of injury and its extent was similar to that noticed in Jonathan apples from the same orchard examined in February. Damage was confined to browning of the tissue round the core and did not prevent the normal development of the fruit.

(2) Time of Incidence.

The first sign of damage was noticed by orchardists on the Moutere Hills early in December. At that time damage appeared to be restricted to the Sturmer variety. No sign of disorder was noticed superficially in a large number of varieties, particularly Jonathan, Delicious, King David and Pearmain, until the middle of February, but an examination of wind-falls and thinnings taken from these varieties early in January showed the presence of the disorder in the form characteristic of each variety. A great part, if not all the damage to the apple crop must therefore have been caused before the end of December.

(3) Dissimilarity to "Bitter Pit."

Injury to apples known under the term "Bitter-pit" has been described by McAlpine in Australia, and by several workers in America. The type of injury in the Nelson district differs both in the manner of its occurrence, in characteristic features, in varieties affected and in time of incidence, from that of "Bitter-pit." "Bitter-pit," as described by McAlpine and as noticed in the Nelson district, is associated during the development of the apple with comparatively small surface irregularity, showing that during the period of apple growth damage is confined to tissue comparatively close to the epidermis. Internal browning of the tissue surrounding the core or the occurrence of dark corky areas in the vicinity of the fibro-vascular bundles have not been recorded by American workers who have investigated the occurrence of "Bitter-pit." Photographs accompanying McAlpine's report on "Bitter-pit" indicate that he uses the term

in a much wider sense than do the American workers. It seems probable, as some investigators have pointed out, that the confluent "Bitter-pit" of McAlpine is produced by different conditions from those causing true "Bitter-pit." It is well known that the Jonathan, Premier and King David varieties are not very susceptible in the Nelson district to "Bitter-pit" injury. These varieties, however, were affected, some to a severe extent, by the disorder which appeared in the past season. On the other hand, Cox's Orange and Lord Wolseley, which are liable to "Bitter-pit" injury, suffered but little damage.

The work of McAlpine and others has shown that "Bitter-pit" is associated with high rainfall or heavy irrigation late in the season. The occurrence of this disorder in a severe form was noted by them whenever rather wet autumn conditions were preceded by somewhat dry weather in the early part of the season. As has already been shown, damage in Nelson orchards was sustained before the end of December, while the apples were immature.

(4) Similarity to "Drought-Spot" and "Cork."

Mix, Brooks and Fisher have described the occurrence of certain diseases of the apple in the United States of America under the terms "Drought-spot" and "Cork."

The descriptions given by them, as well as the appearance of injury shown in photographs accompanying their papers, indicate that there is a close resemblance between the diseases which have appeared in the Nelson district and those described by them under the terms "Drought-spot" and "Cork."

In Nelson the form of injury occurring in the Sturmer variety seems similar to "Drought-spot," while the flesh damage in the Premier, King David and other Nelson apples appears identical to "Cork."

Apparently internal browning of the tissue round the core was not a characteristic feature of damage caused by these diseases in America, for no mention is made of it in the reports which have appeared. In Nelson, on the other hand, Jonathan and Delicious apples very frequently exhibited no other damage except the browning of tissue round the core.

It must be noted that the American workers have drawn a distinction between "Drought-spot" and "Cork" and state that somewhat different soil conditions are frequently associated with the occurrence of the two diseases.

PART II.—OCCURRENCE IN THE NELSON DISTRICT.

(1) Varieties Affected and Characteristic Symptoms of Injury.

In the 1925-26 season only certain varieties suffered severe damage, while others escaped with but a trace of internal browning in the tissue surrounding the core.

The following table, compiled from a large number of observations, shows the degree to which a number of varieties were affected with the disorder in the 1925-26 season :—

Bad Damage.	Moderate.	Slight.	Apparently not affected or damage negligible.
Sturmer	Dunn's Favourite	Cox's Orange	Dougherty.
Premier	Newtown Pippin	Delicious	
Adam's Pearmain	King David	Gravenstein	
Cambridge Pippin	Jonathan	Lord Wolseley	
Ballarat		Statesman	
		Crofton	

The following notes in regard to the form of injury seen in different varieties were made during an examination of a large number of orchards in the Moutere Hill country.

Sturmer.—This variety was badly affected by a severe form of pitting resulting in disfigurement of the apple. In certain cases there was only slight outside disfigurement, but corky areas always occurred in the flesh of the apple.

Premier.—In most cases little surface indication of injury was noticeable but many dark corky areas in the flesh of the apple were invariably found. Occasionally pitting of the surface and serious malformation of the apple occurred.

Adam's Pearmain.—Very frequently the apples showed no outward blemish, but, on cutting, all types of injury from slightly marked internal browning to the presence of many corky areas in the flesh were noticeable. In some cases surface pits occurred, while in others the tissue of the apple including the core was water-logged.

Cambridge Pippin.—In this variety large surface depressions and malformation occurred. The outward appearance of the apple resembled that described by McAlpine under the term "crinkle." In certain cases internal browning of the tissue round the core accompanied severe injury to the flesh of the apple.

Ballarat.—Very little surface irregularity occurred, corky areas and lesions in the flesh were found, and frequently water-soaked tissue extended from the core to the surface.

Dunn's.—Severe pitting affecting the surface of the apple was common, but sometimes injury was only visible when the apple was cut.

Newtown Pippin.—Somewhat similar damage was observed in the case of this variety to that already described for Dunn's.

King David.—Only in severe cases of injury did surface pitting occur. The extent of flesh injury varied from internal browning round the core, to the presence of many corky areas in the flesh. Damage could frequently be detected only on cutting open the apple.

Jonathan.—Very little surface indication of injury was noticeable. Usually, injury was confined to browning of the tissue round the core of the apple within the main vascular system.

Cox's Orange.—There was no easily noticeable external sign of injury. On cutting affected apples, browning of the flesh and sometimes pitted areas were observed.

Delicious.—Damage was generally confined to a small amount of browning round the core of the apple. In addition, the affected apples showed a pronounced softening of the tissue, and a sleepy condition of the flesh.

Gravenstein and *Lord Wolseley.*—In the case of these two varieties there were very few opportunities for examination. In those apples which were examined no outside disfigurement of the apple was seen. Damage was confined to internal browning, and in severe cases to pitting of the flesh.

(2) Tree Characteristics in Relation to Injury.

The orchards where most damage was seen varied in age from eleven to twenty-five years. Fewer opportunities were presented for the examination of young orchards but in those examined less damage was noticed.

Injury was not necessarily associated with either very poor growth or luxuriant growth. In situations where damage occurred, small stunted trees as well as large vigorous trees were affected. In cultivated orchards, the trees suffering least damage were frequently average trees of moderate growth and vigour. Sometimes only certain branches of a tree were affected. These branches often showed rather poor growth and foliage development.

(3) Factors Influencing the Severity of the Diseases.

I.—Nature of the Soil.

Damage from pitting, the presence of corky areas in the flesh or browning of the tissue was confined in both seasons to orchards on the Moutere Hills type of soil or on granite hill-land. Although careful enquiries were made only two instances of the disorder in other parts of the district were reported. In these cases the damage was slight and was restricted to a few trees in each instance.

The soil of the Moutere Hills has resulted from the weathering of a vast alluvial deposit. The material from which the soil is derived consists of much

weathered sandstone, claystone and some granite gravels. These old alluvial deposits have been denuded and in parts deeply intersected by streams and rivers of comparatively modern origin. The topsoil is a greyish loam poorly supplied with organic matter and very low in phosphate, nitrogen and lime. It has a marked acid reaction. The subsoil is heavier in texture than the topsoil and shows local variations in textural qualities on different parts of the apple lands. Owing to erosion the subsoil is very close to the surface on steep slopes.

The granite land used for apple culture comprises gently sloping and steep hill-land. The soil has resulted largely from the weathering of granite rocks. On gently sloping land the soil and substrata have originated from the deposition of material brought from hill-land in the vicinity. On steep hill-land the actual rock, greatly changed by weathering, is found at a depth of three feet. The soil is a brown loam frequently rather shallow. It is heavier in texture than the Moutere Hill soil but is similar in chemical characteristics. The subsoil is a clay usually extending to a depth of twenty inches and affording rather poor drainage. This clay is frequently underlaid by a coarse gritty layer of siliceous fragments.

*Mechanical Analysis of Topsoil and Subsoil of Moutere Hills Land and granite hill-land.**

(Soil has passed through a 3mm. sieve.)

	Moutere Hills.		Granite hill-land.	
	Topsoil.	Subsoil.	Topsoil.	Subsoil.
Moisture	1.2	2.3	1.8	3.2
Loss on Ignition	3.4	4.3	6.8	5.7
Fine Gravel	2.7	3.1	.8	3.1
Coarse Sand	17.3	17.0	11.2	9.7
Fine Sand	35.6	27.5	26.9	22.6
Coarse Silt	19.7	15.8	20.1	14.9
Fine Silt	15.0	17.2	20.6	21.4
Clay	4.4	12.3	11.2	17.5
Total ..	99.3	99.5	99.4	98.1
Stones ..	9%	5%	1%	3%

The disorders did not appear in all orchards either on the Moutere Hills land or on granite land. Damage was commonest on the slopes, particularly on slopes which were steep. On flat land where the soil was deep, no sign of the disorders appeared in any part of the district. Where severe damage occurred the topsoil was inclined to be shallow and frequently was underlaid by a stiff clay or hard pan.

* Samples were taken from orchards severely affected by the diseases.

In certain cases, the affected trees were situated on parts of the orchard which were likely to be very wet in winter-time and which under the cultural methods of the orchardist would tend to dry out quickly in summer. Damage, however, did not necessarily accompany a chronic droughty condition of the soil in summer. Some orchards on open gravelly soils were almost free from injury. On the other hand, a permanent rather wet condition of the soil throughout the whole year did not necessarily predispose trees to severe pitting or browning.

It cannot, therefore, be said that either very open soils or very retentive soils are necessarily connected with the incidence of the disorder.

II.—Influence of Cultivation.

It is a rather remarkable fact that fruit in a number of orchards which have been abandoned for several years and allowed to go into grass showed comparatively little injury.

In one or two cases where orchards have been partially abandoned, one ploughing a year being the only cultivation, severe injury was noticeable on steep hilly country.

In nearly every case severe injury was more noticeable on orchards which had in previous years received comparatively good cultivation, but which, in this season, had received indifferent cultivation during the months of November and December. The amount of damage was markedly less where good cultivation right up to the trunks of the trees had been maintained during the months of November and December. In parts of the same orchards, where cultivation owing to special circumstances had not been given, a great increase of damage was noticed.

III.—Influence of Manuring.

It was supposed by some orchardists that heavy manuring of the trees in past years has been directly responsible for the occurrence of the disorders. Other orchardists have attributed their freedom from serious damage to the fact that manure was applied in the early spring. After a careful examination of a large number of orchards working under all kinds of manurial programmes, no clear evidence could be obtained that severe damage was due to heavy or light manuring In several instances adjoining orchards working under somewhat similar manurial programmes were affected, one to a small extent and the other to a severe extent. On one part of a cultivated orchard a block of King Davids which had received no manurial treatment for three years was as badly affected as any that came under our notice.

While it must be admitted that more extensive damage frequently occurred in orchards which have been well manured in the past, yet it must be emphasised

that several orchards receiving liberal manurial treatment were almost free from damage, notwithstanding the fact that they were situated on slopes, commonly associated with the diseases. Provided cultural operations have been performed carefully, and a good surface tilth obtained early in the season, no greater damage has been sustained in the manured orchards than was the case in cultivated orchards receiving little manurial treatment.

IV.—Influence of Climate.

A study of the rainfall data for the two seasons in which severe damage has occurred, reveals the fact that the rainfall was much below the average for the summer months. The following table shows the rainfall for the months of November and December in the years 1922-25 at different points of the Nelson district :—

Locality.	Nov.-Dec., 1922.	Nov.-Dec., 1923.	Nov.-Dec., 1924.	Nov.-Dec., 1925.
Harakeke ..	5.0″	2.30″	11.75″	1.18″
Mapua	4.49″	2.26″	11.53″	.80″
Nelson	5.32″	4.33″	13.53″	2.0″
Motueka	5.76″	3.53″	13.33″	1.53″

Nelson average for 43 years during November and December=5.62″.

Severe damage occurred in the 1925 and moderate damage in the 1923 seasons. In both cases the rainfall for the months of November and December was greatly below the normal.

Insufficient data are available from which conclusions might be drawn in regard to the influence of sunshine and atmospheric humidity on the incidence of the disorder, but if the hypothesis to be put forward proves to be correct, it would appear probable that low humidity and bright sunshine in the early part of the season combined with dry soil conditions contribute to the severity of injury.

PART III.—CAUSES OF DISEASES.

(1) Views of Previous Workers.

Various hypotheses have been advanced by different workers to explain pitting of fruit, "Cork" and water-core. Mix, commenting on the occurrence of "Drought-spot," "Cork" and similar related diseases of the apple, states that "These diseases may occur in both wet and dry seasons. There is, however, a marked relation of weather conditions to the incidence of the diseases. They tend to disappear in wet weather and are much more serious in a dry season, particularly when dry weather occurs early in the season . . ." "Since, however, in a wet season and in conditions where there seems to be no deficiency

of moisture, these diseases may occur in trees that have been previously diseased year after year, insufficient soil moisture cannot be looked upon as a sole cause." Mix suggests that the leaves rob the fruit of moisture during periods of low root supply and high transpiration. The experiments of Chandler in which it is shown that the concentration of cell-sap is higher in the leaves than in the fruit support this theory. Both Mix, Brooks and Fisher have demonstrated experimentally that pitting of fruit may be produced by withholding moisture from trees and branches after the fruit has attained a certain size. In the experiments of Mix, lesions resembling "cork" injury were observed in addition to surface pitting.

Brooks and Fisher support the conclusions arrived at by Mix in regard to the cause of pitting. Their observations indicate that "Cork" is a form of drought injury. "This disease appears to differ from typical drought spot both in characteristics and conditions of occurrence. With certain varieties of apples "Drought-spot" can apparently be produced on any soil under conditions of sudden and severe drought. Cork seems to be the result of a less severe but more chronic drought on trees located on certain peculiar soils, especially on soils lacking in humus and not retentive of moisture."

The earlier work of Sorauer indicated that water-core was frequently associated with droughty soil conditions. The more recent work of Brooks and Fisher shows that water-core, in certain varieties of apples, is prevalent when the apples have been freely exposed to strong sunlight. Shaded apples are very frequently quite free from the trouble. These workers show that there is a close correlation between sap concentration and water-core. Exposed and sunburned apples have a very high sap concentration and are very susceptible to water-core. Heavy irrigation tends to decrease both sap concentration and water-core.

(2) A Suggested Explanation of the Influence of Various Factors on the Occurrence of the Disease.

In the Nelson district, the characteristic features of pitting and flesh injury agree well with those described by Mix, Brooks and Fisher under the terms "Drought-spot" and "Cork." Although internal browning of the tissue round the core has not been described by the American workers in connection with "Drought-spot" or "Cork," yet the data obtained in this investigation suggest that somewhat similar factors are concerned with the occurrence of the three types of disease.

So far as the occurrence of the diseases in the Nelson district is concerned no line of division can at present be drawn. It is, however, probable, as the work of Brooks and Fisher on water-core has shown, that under certain soil conditions one or more factors may exert a greater influence on the production of one form than is the case with other forms of disease.

Early in the paper, it has been pointed out that the occurrence of the diseases in the Nelson district during both the 1923-24 and 1925-26 seasons has coincided with an extremely low rainfall during the months of November and December. Although there can be little doubt that the low rainfall during the early summer was the greatest contributing factor in the occurrence of the diseases, yet it is impossible to explain its occurrence on certain soils and its non-appearance on others without taking into consideration the apple trees in their relation to the soil.

It is a notable fact that in both the 1923-24 and 1925-26 seasons several orchards situated on certain gravelly soils in the Stoke and Waimea districts of Nelson suffered severely from drought. The foliage of trees in these orchards was flaccid, the fruit was soft to the touch and little bigger than large marbles; yet in these cases there was seldom any damage from the diseases which affected apples on the Moutere Hills and granite soils. In orchards where damage was experienced on the latter soils, normal development of fruit took place unless the apples were badly pitted.

The marked association of trees suffering severe damage with soil conditions unfavourable to tree growth was an important point resulting from the present investigations. The soil conditions whether resulting from shallow topsoil, heavy clay subsoil, hard pan or wet substrata all affected the normal development of the root system of the apple trees. In such cases the roots were frequently ill-developed and invariably lay near the surface. As a result the trees were severely affected by sudden fluctuations in the moisture content of the soil, during times of scanty rainfall and drying winds. The shallowness of the root-system, moreover, made the trees liable to damage through severe cutting of roots by the plough and discs. The water-logged condition of the soil in wet weather where heavy clay subsoil or hard pan occurred likewise caused in all probability the death of a large percentage of root hairs responsible for supplying soil water to the trees. In this connection it must be emphasised that the winter preceding the 1925-26 season was marked by an unusually large number of wet, dull days throughout the whole of September and October. In seasons with an average rainfall during November and December, the loss of some roots through cutting by the plough or by death through submergence in water has produced little apparent injury to the apple crop. Under the conditions which actually occurred in the 1925 season with its low rainfall, bright sunshine and frequent drying winds, it may well be understood that, during the critical period of tree growth and high transpiration of the leaves, the root system of the tree was unable to supply the moisture required for both fruit and foliage development if careful cultivation had not been carried out in the orchard.

In several instances in which the apples on one or two branches only of a tree were badly affected with pitting or browning it was found that severe cutting of

the roots on the same side of the tree had occurred during the last twelve months.

It may seem difficult at first to explain why trees in abandoned orchards overrun with grass were comparatively free from trouble, while those in cultivated orchards somewhat similarly situated in regard to aspect and slope suffered severely. It must be borne in mind that trees in abandoned orchards were making less growth, less foliage development and carrying a smaller crop. These circumstances would give, in an emergency where the moisture content of the soil became low, an advantage over the trees in cultivated orchards where growth, foliage development and size of crop were greater.

Although the presence of grass growing over the roots of the trees has a bad influence on the growth and development of the tree, yet it ensures more even moisture conditions in the top-soil during winter periods of heavy rain and dry weather in the spring time. During the months of September and October the grassed orchards were probably not nearly so wet as the cultivated orchards which had been ploughed and left rough, and in the dry period which followed, the grass acted for some time as a mulch, maintaining a moister and cooler surface soil. In the cultivated orchards, owing to the setting down of the ground, the top-soil dried much more quickly. It is also probable that the absence of disturbance to the roots of the trees in abandoned orchards was a material factor in the comparative freedom from disease which such orchards exhibited.

The facts which have been obtained concerning the occurrence of the diseases point clearly to a deficiency of moisture as being inseparably connected with their production. Shallowness of root system, damage to roots either by cutting or by submergence in water, lack of cultivation, bad textural qualities of the soil, bright sunshine with drying winds and a very low rainfall have all been associated with severe damage. They are all factors which operate directly or indirectly in the maintenance of low amounts of moisture in trees. In years of average rainfall, soil conditions are such as to permit normal development of fruit and foliage, but, in years of low rainfall, the soil factors which have been mentioned hasten the rapid drying out of the soil and a deficient supply of moisture in the trees. If the deficiency occurs at a critical time when growth and high transpiration from the foliage are taking place, the leaves would transpire to the detriment of the apples. The experiments of Mix have shown that actual injury resembling "Cork" and "Drought-spot" can be produced in this way.

In isolated cases it frequently is difficult to explain why one tree suffered and an adjoining tree escaped damage. If it were possible to obtain a true picture of the root system of the two trees, actually to measure the growth and foliage development in relation to the extent of the root system and to compare the moisture content of the soil under the trees in question at the time that

damage occurred, an explanation of the difference in susceptibility would probably be found.

Although the cause of the diseases is inseparably connected with a deficient supply of moisture, it is impossible, at the present time, to state what was the direct cause of the death of the apple cells.

PART IV. PREVENTIVE MEASURES IN REDUCING THE SEVERITY OF THE DISEASES.

Although much work remains to be done in connection with the whole question, yet the facts which have been elicited indicate the desirability of (1) the encouragement of deeper rooting in apple trees by the removal of such undesirable features as hard pan, seepage, etc.; (2) the conservation of soil moisture by adequate cultivation and mulching; (3) better cultural methods in handling orchard soils; (4) the continuance of manurial programmes adapted to the needs of each soil type and their local variations, provided that recommendations in (1), (2), (3) have been carried out.

In certain cases it seems doubtful whether anything can be profitably done to ensure absolute freedom from the diseases under conditions of extreme fluctuation in the rainfall.

(1) Cultural Methods.

The encouragement of a deeper rooting-system of the trees should be a first consideration for orchardists who have suffered much loss. Where seepage or hard pan occurs, the top soil possessing otherwise no disadvantage from the point of view of apple culture, the use of a subsoiler or pan breaker in the centre of the rows in order to break the hard pan, the extension of tile draining in the orchard and the use of more lime will all improve the suitability of the soil for tree growth. As a result the trees will root more deeply and will not be so liable to sudden variations in climatic conditions.

Perhaps the most important preventive measure which the orchardist has to his hand is that of better cultivation during November and December. It must be borne in mind that in order to give maximum benefit, cultivation must be carried over the entire root system of the trees.

The introduction of the pipe line method of spraying should prove a great boon to orchardists, since the compacting and treading down of the soil by the passage of the spray cart is avoided. More time will also be available for cultivation.

Greater care must also be exercised in the handling of the soil. Ploughing near the trunks of the trees when the top-soil is shallow must be avoided on account of the great damage which results to tree-roots. The practice of

ploughing-off from the trees, and leaving the roots almost exposed for months at a time, is one which must be strongly condemned.

(2) MANURIAL TREATMENT.

In view of the splendid results both on tree growth and yield of fruit which have accompanied the use of lime and manures on certain poor apple lands in the Nelson district, e.g., Moutere Hills orchards, it is highly desirable that manurial treatment should be continued. Provided that the recommendations given under the head of cultural methods be adopted, there is little reason to fear, even in exceptional years of low spring rainfall, that the extent of damage through browning and pitting will be materially increased by the continuance of manurial treatment.*

Where, however, economic considerations preclude the possibility of improving soil conditions so that deeper rooting of trees and better tilth of soil are not obtained, it seems desirable to avoid the use of large quantities of nitrogenous manures. It appears possible, under these circumstances, that nitrogenous manuring, by promoting a larger leaf system, would encourage, in times of very low rainfall, the development of pitting and browning. No evidence, however, has been obtained during this investigation to show that the manurial treatment commonly practised by orchardists has been a weighty factor in increasing the severity of the disease.

(3) OTHER REMEDIAL MEASURES.

The cases which present most difficulty in treatment are those in which trees have been planted on steep slopes and those in which a heavy clay underlies a somewhat shallow topsoil. In regard to trees planted on steep slopes, more careful measures must be taken to prevent erosion of the soil and the exposure of tree roots.

In certain cases the practice of ploughing on to the trees twice in succession for every once that the land has been ploughed away from the trees has resulted in a greater depth of soil over the root system of the trees. Such evidence as could be obtained indicated that where this had been done the amount of damage was considerably reduced. The adoption of such a procedure, however, may not entirely eliminate the possibility of browning and pitting under extreme

* The following manurial programme has been recommended by the Cawthron Institute and has been adopted by many orchardists on the Moutere Hills :—

(1) Initial treatment of the land with 2 tons of ground limestone per acre, followed every four years by a further dressing of 1 ton per acre.

(2) A regular system of green manuring with leguminous crops such as blue lupins, horse beans or tares. These crops are sown in the early autumn and are manured with 3 cwt. superphosphate and 1 cwt. sulphate of potash per orchard acre.

(3) The following additional manurial treatment, given in the spring, for trees lacking in growth and vigour : 3 lbs. of fish manure or a mixture of 3 lbs. of superphosphate and 1 lb. of dried blood per tree.

climatic conditions. Where such land is worth keeping in orchard, the sowing-down of the alley-ways between the trees to red, white or subterranean clover is worthy of consideration. If such a practice were adopted, it would be advisable to hand-hoe areas around the trunk of the tree and to increase the annual application of manure. The practice of sowing down an orchard to clover or grass seldom can be recommended on good soils suitable for apples under New Zealand conditions of culture, but on steep slopes where cultivation is difficult, damage to tree roots highly probable, and erosion of soil difficult to prevent, the use of clover may well be highly advantageous.

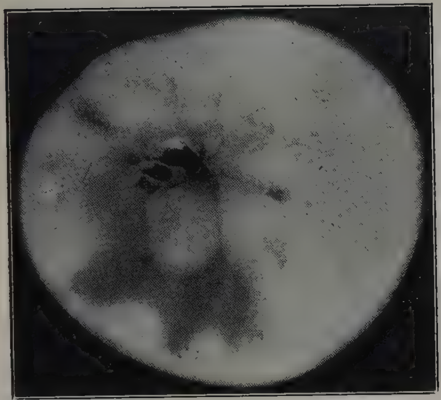
In situations where apple trees have been planted in a shallow top-soil underlaid by heavy clay, deeper ploughing between the rows of trees has not greatly reduced the severity of damage. In a number of cases examined, it was found that a much deeper penetration of the roots had been obtained in the parts which had been ploughed deeply. During times of heavy rainfall, however, these deeply ploughed slopes become very wet and great damage must be done to root hairs. Owing to the shallowness of the top soil, much intractable clay has been brought to the surface by the plough. This bakes into hard lumps if caught with a hot sun and drying wind, making it very difficult to secure a good tilth. It is possible that deeper draining and a much greater use of lime may do much to improve the soil so that more even conditions during extremes in rainfall will be maintained. Evenness in the moisture content of this soil is probably the most important factor in reducing the severity of the diseases. It is interesting to note that in two orchards with heavy clay subsoils a number of grassed trees were decidedly less subject to pitting than trees in the cultivated part of the orchards. Where the slopes were steep, however, this did not prevent the occurrence of a certain amount of pitting and browning.

SUMMARY.

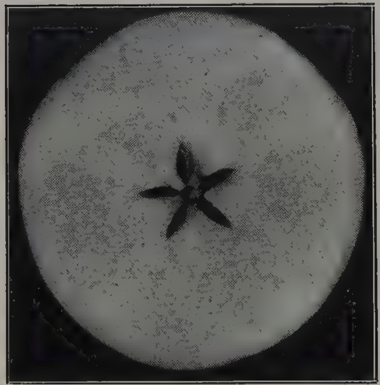
In the present paper, the occurrence, incidence and characteristic features of certain apple diseases in the Nelson district during the 1923-24 and the 1925-26 seasons have been described.

1. In many ways, the symptoms and occurrence of the diseases resemble those of "Drought-spot" and "Cork" as described by Mix, Brooks and Fisher. The occurrence of browning in the tissue round the core without the presence of corky areas in the flesh, however, was not described by them. The data obtained in the investigation suggest that somewhat similar factors are connected with the occurrence of the three types of disease.

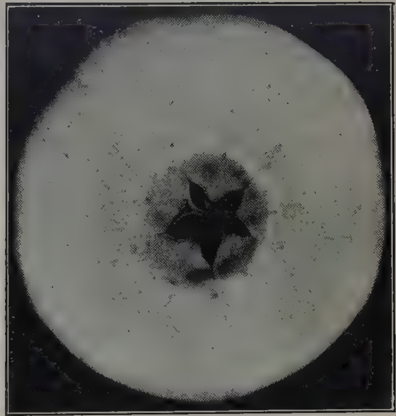
2. The diseases appeared in orchards on two only out of eight types of soil used for apple culture. These soils are in the main well adapted to apples, but



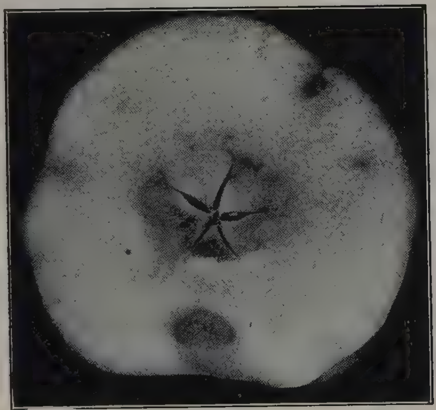
Ballarat (Median Section), showing pitted flesh and water soaked tissue.



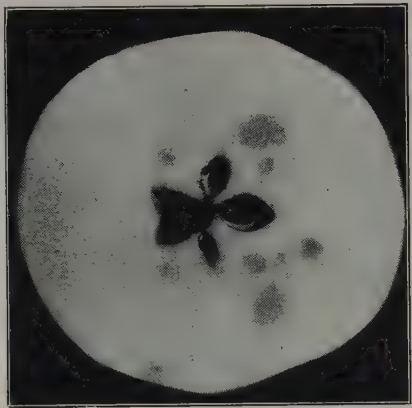
Delicious (Median Section), characteristic type of damage. A small amount of browning of the tissue surrounding the core.



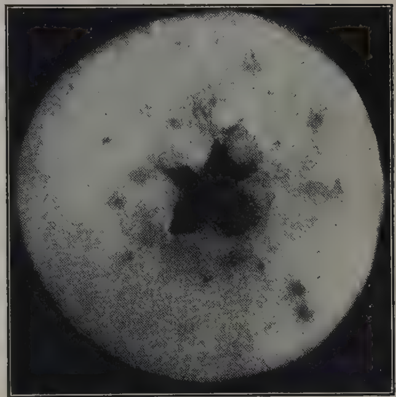
Jonathan (Median Section), showing browning of the tissue around the core. No surface indication of injury.



Cambridge Pippin (Median Section). Usual type of injury, showing mal-formation of the surface and corky areas in the flesh.



Adam's Pearmain (Median Section) showing areas in the flesh. Little surface indication of injury.



King David (Median Section), showing browning of tissue around the core and minor damage in the flesh. No surface indication of injury.

Sturmer. Typical hemispherical pitting of the surface.

Sturmer (Median Section). Surface pitting and deep-seated corky areas in the flesh.

in places the top-soil is shallow and the subsoil is unsuitable. Where the soil is deep, little damage has resulted from the diseases.

The trouble has been most severe wherever unsuitable soil conditions have encouraged surface rooting or favoured liability of damage to roots through submergence in water or by orchard implements.

3. The fact that in both seasons of serious damage there was an abnormally low rainfall during the months of November and December, suggests that a deficiency of soil moisture was the most important factor involved in the occurrence of the diseases. The non-appearance of the diseases on open gravelly soils shows, however, that chronic droughty conditions are insufficient to account for their appearance.

4. Injury to the apple crop may be explained best as being due to a temporarily insufficient supply of water from the roots of the trees at a time when transpiration from the leaves was great. The climatic and many soil conditions associated with the occurrence of the diseases strongly support this contention.

5. Various measures have been suggested for reducing the liability of trees suffering severely from the disease. It must, however, be recognised that in certain cases it is extremely doubtful whether anything can profitably be done which will ensure entire freedom.

In conclusion, the authors express their thanks to many orchardists who have given every facility for making observations. In particular, they acknowledge the help given by Mr. J. H. Thorp, Orchard Instructor, Nelson, in reading certain sections of this paper and in furnishing valuable information.

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THE EFFECTS OF STRAWBERRY APHIS
(*Capitophorus fragariæ, Theobald*)
ON THE STRAWBERRY PLANT.

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AND

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HISTORY.

The first record of this aphis affecting cultivated strawberry plants was made by Buckton (2) who stated that he did not see the garden strawberry attacked before the year 1876, but in June of that year the stalks of the unripe fruit were much infested. Theobald (11) obtained his first intimation of aphis damage from Mr. Harvey S. Bickham, of Ledbury, in the first week in May, 1905. The variety attacked in this case was Stirling Castle. The estimated damage at that time was expressed as follows by Mr. Bickham: "Though the attack is certainly a severe one, I cannot say that the blooms, which are now in profuse numbers, are on the whole smaller than they should be, but the stalks which carry them are not so thick and vigorous as they should be." Theobald (11) who kept some plants sent to him under control in the open, stated that the trusses of bloom did not suffer very much, but the fruit was affected to no small extent. Yet in spite of what was undoubtedly a very severe attack at Ledbury the grower picked over two tons of fruit to the acre. The same author further states that not only does the aphis prevent many trusses from bringing their fruits to a marketable size, but many of them settle on the fruits themselves, sheltering between the fruit and the calyx. The aphis causing the damage at Ledbury was Siphonophora fragariella, Koch. Theobald in his Annual Report for 1907 (10) refers also to damage to strawberries under glass, at Bramley, by *Siphonophora fragariæ*, Koch. According to Davidson (3) *Siphonophora fragariæ* is now known as *Macrosiphum fragariæ*, and *Siphonophora fragariella* as *Amphorophora fragariella*. Theobald does not record having made any field observations on *Capitophorus fragariæ*, Theob., the aphis with which this paper is concerned. In the report on the occurrence of insect pests and fungus diseases on plants in England and Wales in the year 1917 (Misc. Publications, No. 21) of the Ministry of Agriculture and Fisheries, no mention is made of strawberry aphis. In the Ministry's report for 1920-21 (Misc. Publications, No. 39) the following statement concerning strawberry aphids appears:

"In 1921, a severe attack of aphides on strawberries took place in the Cheddar Valley, where the majority of the Laxtons were affected. Royal Sovereign and Kentish Favourite suffered less (Walbank). Proudlock also noticed strawberries affected at Cottenham in June. In July, Gray records a bad attack in Northumberland on old plants of Macmahon. The species were not identified, so it is impossible to say whether the damage was due to *Macrosiphum fragariæ*, Koch., or *Capitophorus fragariæ*, Theo. The former was found in Kent in two localities on strawberries, but not in sufficient numbers to do any harm." In a similar report (Misc. Publications, No. 49) for 1922-24 there is no mention whatever of any strawberry aphis.

Infection Experiments with *Capitophorus Fragariæ*.

In the Spring of 1925 potted plants of different varieties of strawberry were brought under greenhouse conditions at the Research Station, Long Ashton, for certain experimental purposes. The runners from these plants were pegged down in pots containing sand kept moist with a complete nutrient solution. As the summer advanced it was observed that the newly formed leaves of some of the parent plants became crinkled and small as compared with other parent plants of the same variety. Furthermore, the runners from the above plants showed the same symptoms as their parents. The treatment of the sand in the pots was identical throughout. Closer examination soon revealed the fact that the parent plants which produced small crinkled leaves, and the runners from these plants, were infested with aphids; whilst the more normal parent plants which produced runners with normal leaves were found to be free of aphids. This raised the question of these marked differences between the runners being due to aphis attack. Further observations in the field supported this possibility so definitely that it was the nature of the damage to strawberry plants caused by this species of aphis. For this purpose several experiments were made. They are described below.

EXPERIMENT I.

Twenty-four of the best procurable runners were lifted on August 23rd, 1925. Twelve of these runners were immersed before planting in a .05 per cent. Nicotine and 1 per cent. soft soap solution for five minutes. Previous trials with the above solution had established the fact that all aphids were killed and that neither the roots nor the leaves of the plants were in any way damaged. These runners were then planted in twelve-inch pots containing a rich compost of soil and dung. The other twelve runners were similarly planted, without special treatment of any kind. On the following day these last twelve runners were infected with fifteen aphids per plant.

The runners, although selected as nearly as possible of equal size, were in different stages of growth. The youngest visible growth in some consisted of folded leaves still enclosed within the sheath, whilst in others they had emerged to various extents and in some cases the young leaves were about three inches long.

Daily inspections were made of the control and infected plants.

On the latter a few days after infection it was found that the aphids were making their way down to the young developing leaves, even before the latter had appeared from the bud. (It was found later that the aphids had a distinct preference for the most tender and succulent young growth rather than the older, coarser and fully expanded leaves). At first the plants grew rapidly and the numbers of aphids sucking on each plant were not sufficient to cause any marked symptoms. Later, it was found that the aphids cast their skins and within a month had multiplied rapidly, while the young leaves were covered with exuviæ.

The control plants remained free from infection until October 28th, when two aphids were found on one plant and several on another. The two aphids on the former were removed. The other plant was placed near the group of artificially infected plants and left untouched so that the effects of aphis infection at this stage could be observed. By this date no aphids nor symptoms of aphis damage were observed on the remaining control (Plate I., Fig. 1). The infected plants showed at this stage distinct crinkled, dwarfed and yellowish green leaves (Plate I., Fig. 2).

Later, at the end of November, the infected plants had become very heavily infested and the latest formed leaves were smaller, more crinkled, and of lighter green colour. (Plate V., Fig. 5.) Further, where portions of the very young leaves had been sucked in many places close together, it was found that after expansion to full size,—in some cases one centimetre per leaflet only—there were small areas of brown, dead tissue in the leaf lamina. Thus the aphids by excessive sucking can cause local scorch areas on the lamina. In rare cases some of the leaflets were so badly damaged that they turned brown and were killed. Such leaflets later fell off, the compound leaf being then reduced to only one or two small, crinkled and deformed leaflets. The total assimilating leaf area being reduced in this way to only a fraction of what it should normally be, it follows that the equilibrium of root to shoot must be temporarily upset. This probably explains the forcing into growth of lateral crowns of the plant, which subsequently occurred on the attacked plants. (Plate V., Fig. 5). These laterals were in turn attacked and affected in a similar way. Another point of considerable economic importance noted was that the attacked plants produced abundant flower trusses earlier than the normally growing plant; the fruit produced from these was small, mis-shapen and of low market value. The actual

number of fruits produced on the infected plants was greater than on the healthy plants.

The method of attack is as follows. The aphids travel to the young buds and feeding on them, are carried up with the expanding leaves. When the latter are half expanded, the majority of the aphids make their way down and creep between the folds of the bud which is still enclosed in the sheath. (Plate II.) They are again in turn carried up on the next succession of young leaves and in due course creep down as before to the tender tissues of the still younger leaves. If conditions are unfavourable to rapid growth, it follows that they have a comparatively long period of time in which to suck and damage each successive leaf. On the other hand, if conditions are favourable to rapid growth of the plant, they have less time in which to cause damage on any individual leaf. Thus the very important practical points that manuring and good cultural conditions are beneficial, as measures for minimising the damage caused by this pest, are clearly indicated.

Aphids can be found in large numbers on perfectly normal and fully expanded leaves which show no sign of any symptoms of disease. The aphis causes observable damage to the leaves only when they attack them in a very young and tender state. Even then the amount of damage depends on a number of factors, including the rate of growth of the strawberry plant, weather conditions affecting the reproduction of the aphis and the number of aphids present at the time of planting.

It may be pointed out that certain of the foliage effects recorded above as directly due to aphis attack appear to be identical with some of the characters observed by Ballard and Peren (1) on plants described in their paper on " Red Plant," " Cauliflower " and " Small Leaf " diseases of the strawberry.

EXPERIMENT II.

Several pot plants, of the variety Royal Sovereign were selected for this experiment. They were already attacked by aphis and in addition were producing runners. The characters of the experiments on these and the results are described below for two plants A and B illustrations of which are given in Plate III., Fig. 1 and 2.

Two runners were taken from plant A, one of which was kept free from aphis by means of a band of vaseline round the stolon. (It should here be mentioned that runners became infected very readily by the aphis walking along the stolon. Further, the runners were inspected each morning and any aphids observed picked off with a brush). This plant was allowed to produce one other runner, which was permitted to become infected naturally. Runner 2. (It is the right hand one in Plate III., Fig. 2).

The other pot plant, B, produced one runner, which was allowed to become infected naturally.

The runners in each case were pegged down on August 29th, 1925. Those runners which were kept free of aphis developed normally (Plate III., Fig. 1), though they were not very vigorous owing to the fact that their parent had suffered a good deal from aphis. No crinkling or yellowing of the leaves was observed. On the other hand, whilst the runners which were allowed to become infected also produced normal leaves at first, before the aphis had increased sufficiently to affect them, when the aphids had multiplied and become comparatively numerous, leaves much smaller than those first formed, and much crinkled and of a yellowish green colour were produced. (Plate III, Fig. 2). It was obvious that the parent plants of these runners had received sufficient check from aphids to prevent the runners making really good plants. Apparently some twenty aphids are sufficient to damage seriously these slow growing runners. Had they been strong runners like those used in Experiment I., it is thought from experience already gained that they would have grown more luxuriantly and more aphids would have been required to produce serious damage.

EFFECT OF APHIS ATTACK ON THE ROOT SYSTEM.

One each of the control and infected plants in Experiment I. were lifted out of the pots on November 25th, 1925, with the ball of soil attached to the roots. The soil was then washed off carefully under a running tap so as to avoid, as far as possible, damaging the roots. It was found that the control plant (Plate V., Fig. 1)) which had a good leaf development also showed a correspondingly good and efficient root system. On the other hand, the infected plant (Plate V., Fig. 2) had a dwarfed and flattened top and a root system in the same proportion. Similar observations were made in the case of the infected and control runners in Experiment II. (Plate V., Figs. 3 and 4).

Thus the damage caused by aphis is not confined to the leaves. The root system is also weakened, in due course, in proportion to the damage caused to the plant above ground. It follows that plants which are restricted in leaf and root development, as the result of aphis attack, cannot produce fruit of such a high standard of perfection as strong, healthy, and robust non-affected plants.

CAPITOPHORUS FRAGARIÆ AS A POSSIBLE VIRUS CARRIER.

The results of recent research on aphid attacks on potatoes and other plants make it necessary to consider the possibility of the strawberry aphis being also a carrier of a virus which may cause the observed damage to the plants.

The healthy and normal runners in Experiment II., it will be noted, were produced by a parent plant which was definitely affected by aphis. Further, some of the runners which were allowed to become infected were borne by the same parent plant as those kept clean. If the virus was present in the parent plant, presumably it could be carried in the cell sap through the stolon. No suggestion of the presence of a virus was noticed in any instance. Further, during the course of these investigations, a heavily infested aphis plant in a pot accidentally dried out so that it partly wilted and the aphids disappeared. Later it was watered and the plant recovered and produced normal shaped though somewhat smaller leaves. (Plate IV., Figs. 1 and 2).

These observations lend no support to any virus theory in connection with this particular aphis. Further work, however, is proposed to settle this point.*

THE LIFE HISTORY OF *CAPITOPHORUS FRAGARIÆ*.

The detailed life history of this aphis still remains to be worked out. Theobald (11) in his account of *Siphonophora fragariella* (*Amphophora fragariella*) states that "the eggs are laid in the winter on the undersides of the older leaves and it is in this state that they hibernate." He records the eggs as hatching between the March 12th and April 5th. So far as the writers are aware, however, the aphis, *Capitophorus fragariæ*, with which this paper is concerned, does not seem to lay eggs in the winter on any part of the plant above the ground. Up to January 4th, 1926, after several weeks of exceptionally severe frosts, aphids of different stages could be found on the undersides of the leaves, particularly the older ones. Under greenhouse conditions, in the autumn, winged forms were produced. Critical observations are now being made in order to obtain a more complete knowledge of the life-history of this pest.

CONTROL MEASURES.

Although no formal trials on control have, as yet, been carried out in the field, the investigation has already suggested the following cultural points which may be advised for ordinary practice.

(1) Runners should be dipped, before planting in the autumn, in soft soap and nicotine wash. The strength should be a one per cent. solution of soft soap containing .05 per cent. of 98 per cent. Nicotine. The runners should not be tied in bundles for dipping, since the wash will not wet them thoroughly.

* Since the time of writing of this paper, a new disease of the strawberry has been described in California (9 and 10). The disease there is known as "Strawberry Yellows" and, as far as can be seen from the account and illustrations given, the symptoms are identical with those described in this paper. The disease is now accepted in California as being caused by a virus, probably carried by insects. An aphis (*Myzus fragæfolii*) is thought to be the principal vector.

They should be allowed to remain in the wash sufficiently long to be completely wetted, then stirred gently round with the hand once or twice and shaken with care on removal.

(2) In addition to dipping, the selection of runners should be practised. This is most important, since the best runners are thus obtained and will, in the majority of cases, be found to have come from parents free from aphis.

Summary of Symptoms of the Disease.

The effects of an attack of aphis on the strawberry plant as observed up to the present may be summarised as follows :—

(i.) Crinkling of the leaf.

(ii.) Occasional splitting of the leaf.

(iii.) Reduction of size of the fully developed leaf.

(iv.) The development of a yellowish-green tint in the leaf, particularly round the edge of the lamina.

(v.) In the case of a heavy attack, serious damage to one or sometimes two of the leaflets, which may become brown and wilted and subsequently fall off, leaving only one or two leaflets instead of three.

(vi.) Frequently, shortening and thickening of the petioles.

The cumulative effects of an aphis attack on unexpanded leaves, continuing over a period of two or three months are :—

(*a*) The leaves become smaller and smaller successively as time goes on.

(*b*) The proportion of leaves with a reduced number of leaflets increases.

(*c*) The petioles become very short and fleshy.

(*d*) The plant assumes a flattened appearance due to the shortness of the petioles and the forcing of lateral crowns occurs as the results of the check to the main crown given by the attacks of the aphis. Aphis attacked maiden plants produce lateral crowns prematurely.

(*e*) A bad attack of aphis before or during the important root-forming period, July-December (6 and 7), leads to a considerable reduction in the amount of root formed. In that event, even if no subsequent attack of aphis takes place, the plant and its crop suffer the following season.

(*f*) When the aphis attack ceases, for any reason, during the growing season, the leaves produced subsequent to the cessation of attack, although not deformed, are much below the normal size.

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EXPLANATION OF PLATES.*

Plate I.

Fig. 1. Photograph of some of the Control Plants in Experiment I. Date of planting August 23rd, 1925. Photograph taken October 28th, 1925.

Fig. 2. Photograph of some of the infected plants in Experiment I. Date of planting and photographing as in Fig. 1.

* The photographs were taken by Mr. G. H. Jones, Laboratory Assistant at the above Station, to whom thanks are due. The authors wish to state that the yellow edges of leaves do not show in the photographs, since at the times at which the photographs had to be taken no light filter was available.

Plate II.

Fig. 1. Photograph illustrating the partiality of Strawberry Aphids for young succulent tissues. Note also the cast skins on the petioles of the older leaves.

Plate III.

Fig. 1. Control runners in Experiment II. These runners were pegged down on August 29th, 1925 and photographed on October 20th, 1925.

Fig. 2. The infected runners in Experiment II. Date of pegging down and photographing as in Fig. 1.

Plate IV.

Fig. 1. A plant showing the results of aphis attack.

Fig. 2. The same plant showing producing normally shaped but somewhat undersized leaves after the infestation by aphis had ceased.

Plate V.

Figs. 1—4. Control and infected plants, taken from Experiments I. and II. respectively, showing the effect of aphis attack on the development of the root system. Photograph taken on November 25th, 1925.

Fig. 5. An infected and control plant from Experiment I. showing the condition of the plants on November 25th, 1925.

PLATE I.

Fig. 1.

Fig. 2.

PLATE II.

FIG. 1.

PLATE III.

FIG. 1.

FIG. 2.

PLATE IV.

FIG. 1.

FIG. 2.

PLATE V.

FIGS. 1. 2. 3. 4.

FIG. 5.

STUDIES IN THE PHYSIOLOGY OF FRUIT TREES.

I. THE SEASONAL STARCH CONTENT AND CAMBIAL ACTIVITY IN ONE- TO FIVE-YEAR-OLD APPLE BRANCHES.

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Introduction and Review of Literature.

The tree is a unit made up of parts which may vary in age from a few weeks to many years. The wood parenchyma and medullary ray cells of the outer annual rings may remain alive for many years, and along with the cortex and phloem tissues exhibit a regular seasonal change in starch content. In 1879 Mer (18) made observations upon these changes, and in 1882 Russow (26) extended this range of examination to include ninety-two species. Russow found that the greatest variation was in the phloem which showed a starch maximum in late autumn and disappeared in winter. In a mild winter some trees kept their starch. Of a large number kept in a warm greenhouse all the winter, about half showed the same starch disappearance as those kept outside. He concluded therefore that the starch change was independent of immediate climatic conditions. Fischer (5) after making a large number of observations, attempted a classification of trees based upon the behaviour of their starch content during winter. He said that in general the soft wood trees dissolve all their starch in winter, and the hard wood trees retain it, especially in the xylem. He found that tree stems showed a starch maximum at leaf fall and a starch minimum in winter. This winter minimum was followed in early spring by a second starch maximum, to be again followed about the time of maximum leaf development by a second and lower starch minimum. Leclerc du Sablon (4) found that starch diminished during winter and increased again in spring. He also noted that as a rule the maximum carbohydrate content was accompanied by minimum *starch* content, and that a maximum carbohydrate and a minimum water content coincided. Preston and Phillips (23) found that there is in general in the stems of all trees in temperate climates, a reduction in the amount of starch in November and December. The extent of the reduction varies considerably. They were unable to support Fischer's classification of trees upon a basis of starch content in winter. Fabricius (6) examined the seasonal starch distribution in large spruce trees. His observations point to there being a general increase of starch in early spring, but of short duration. By April 22nd it had largely disappeared from the upper parts of the trees, the disappearance being in proportion to cambial activity. The re-deposition of reserve food began in the bark.

More recently the subject of reserve carbohydrates in woody stems has been again under review. Tottingham, Roberts, and Lepkovsky (29) regard the hemi-celluloses as important substances. While this may be so, from the present point of view the starches are regarded as more indicative of immediate seasonal changes in metabolism. Cameron (2) found that with pear and apricot there was the same seasonal fluctuation in starch content as that recorded by Fischer, i.e., two maxima and two minima. He also found that in spring the starch began to disappear from the phloem first of all, in both apricot and pear. As regards the vertical order of starch disappearance in spring, it began in the tips of the young shoots and worked basipetally. Price (21) in a more extensive survey found that during the dormant season starch was present in the pith, wood parenchyma and medullary ray cells of apple stems. As spring approached it appeared in the bark, then as leaves appeared starch disappeared from the bark, wood parenchyma and medullary ray cells in the order named. The disappearance began in the younger branches and worked downwards. Mitra (19) records a very low starch content in two-year-old apple seedlings soon after growth started. Throughout the summer starch content increased up to October, but when the cold weather set in it began to decrease and continued to decrease until February. Butler Smith and Curry (1) also made observations, which in so far as they cover similar ground are in agreement with the observations of Price, Mitra, and Cameron. There is therefore an undoubted seasonal change in starch content which on the whole shows two maxima and two minima, the maxima occurring respectively at leaf fall and very early spring; the minima at the time of maximum leaf growth and early winter.

The winter or early spring minimum is the most difficult to explain and has generally been assumed to be due to the winter cold. This idea is largely due to Fischer and the various authors cited by Pfeffer (22). Russow (27), however, regarded it as a *fixed habit* of the tree, inasmuch as trees kept in a warm greenhouse all winter, lost their starch. He regards it as a fixed habit influenced to some extent by immediate temperature conditions. Preston and Phillips also regard the winter starch disappearance as being dependent more upon season than temperature. Russow, however, does report some species which retain starch in a mild winter but lose it in a more severe one. Chandler (3) rightly points that whereas Tuttle (30), Price (21), Hooker (14), and Mitra (19) all worked in districts having a continuous frost from December to February, yet Cameron (2) worked at California where the winters are particularly mild, and they all record this temporary low starch content during winter. It is clear, therefore, that its relation to the weather conditions cannot be explained solely upon a basis of temperature.

In the present paper importance is attached to the order of starch disappearance in respect to the age of the branches. Pfeffer (22, I.c. p. 604) quotes

several authors, particularly T. Hartig, for the statement that the starch reserves of stems disappear from above downwards. Hartig concluded that the deposition of starch began at different times in different species, and that it began in the lower parts of the stem and worked upwards, reaching the terminal twigs last. Wotczal (32) says that in spring the starch transformation begins in the distal parts of both roots and shoots and works towards the older part of the tree. Normally these two waves of starch disappearance do not encounter one another so that there is a region of undepleted starch at the base of the stem. He also says that the re-disposition of starch is from the older parts towards the younger ones. Gardner (7) records the order of starch disappearance and re-appearance in the various tissues of one-year-old Bartlett Pear shoots. He found that in spring starch disappeared first from the whole of the phloem and then from the xylem tissues from the tips of the branches downwards. Starch was completely absent throughout the growing season, but the re-deposition began immediately upon the cessation of elongation growth. This re-deposition began in the apical region and progressed downwards. Cameron (2) reports that in pear and apricot starch disappearance was from above downwards. Price also records it for apples. Hodgson (13) for cuttings of apples, cherries, peaches and plums. Thus all workers are agreed that there is a *downward* disappearance of starch in spring, but they are not agreed as to the order of re-appearance in late Summer.

So far as the writer is aware no attempt has previously been made to relate the dominant phases of this starch cycle to other physiological phenomena, such as cambial activity, the presence or absence of buds, although there are scattered references to it in the literature. In the present work emphasis is laid upon the succession of events as they occur at various heights along ten-year-old branches, and upon the relationship between cambial activity and the starch cycle. The more important publications upon radial activity have been collected together by Grossenbacher (8), who gives an extensive bibliography. On page 5 he summarises as follows, "But in general cambial activity is said to begin in one-year-old shoots just back of unfolding buds, and to proceed downwards to the larger branches and trunks on which it usually begins uniformly and at about the same time from top to bottom." Hastings (11) made a large number of observations and found that in the broad-leaved species examined there was no increase in thickness until the buds were opened. The first formation of new wood was in the neighbourhood of the terminal buds and was not continuous round the stem. Growth progresses downwards and when it reaches the five-six-year-old branches it becomes rapid and continuous over the whole tree. In Gymnosperms on the other hand, growth began in the two-three-year-old parts before the buds were open. In Hemlock, at the end of May, growth was greatest in the six-seven-year-old shoots and decreased up

to one-year-old shoots where it was very slight. The defoliation and disbudding experiments of Lutz (17) indicate clearly that the initiation of radial growth is from above downwards. The observations of Hartig (10), Rubner (23), and Harper (12), show that under certain conditions particularly defoliation, radial growth may be omitted for several years at the base of trees, although it takes place in the terminal regions.

Finally there is the relation of buds to the development of cambial activity and starch disappearance. The experiments of Jost (15-16) indicate that there may be a causal relation between the presence of developing buds and radial growth. Defoliated pine branches were found to undergo radial growth provided the terminal buds were not removed, whereas when the last grown leaves and terminal buds were removed there was very little or no radial growth. Lutz (17) disbudded young Fagus sylvatica and Pinus silvestris trees at various times. The trees disbudded on March 20th showed but minor fluctuations in starch content during the following summer, but a complete disappearance in December. The branches remained healthy but no radial growth took place. Nördlinger (20) found that trees with all their branches removed in winter showed little or no radial growth in the following year. The work of Vochting (31) on decapitating and budding herbaceous plants, and the observations of Reiche (24) who found that in Chili radial growth of trees did not occur unless bud break preceded it, strongly suggests that cambial activity is in some way closely associated with bud development, and rarely occurs without it.

The present paper is an attempt to record the seasonal changes in starch content as they occur in normal bush type apple trees, along with observations upon the seasonal changes in cambial activity. Particular attention has been paid to the order of starch disappearance and re-appearance and to the beginning and cessation of cambial activity.

A discussion of the significance of the facts recorded is deferred until the publication of the second paper of this series, which will deal with the results of experiments on the effect of double-ringing and disbudding upon starch content and cambial activity. The discussion is delayed since it is desirable that both sets of facts should be considered in relation to each other.

Experimental Method.

The data were obtained from two sets of experiments, (*a*) young trees brought into the greenhouse, (*b*) trees growing in the plantation. In the former, five-year-old trees which had been growing in pots for three years were taken into a warm greenhouse on February 2nd, 1926. These trees were less vigorous than such trees would normally be and a large number of the lateral buds—even on the 1925 growth—had developed into fruit buds. Restricted root growth was undoubtedly the cause of this diminished vigour. At suitable intervals

after taking into the greenhouse long spurs and terminals were gathered and examined for starch content and cambial activity. On February 25th and March 17th, 1926, trees were cut off at the graft level and examined as above. This experiment extended over the period February 2nd to March 17th, 1926. In the case of the outdoor trees, shoots and spurs were gathered from ten to fourteen year old apple trees at suitable intervals throughout 1926. Spurs and terminals of Magnate Pear trees and Bramley Seedling apple trees were also kept under observation in the same way during the period March 1st to May 30th. These latter observations furnished corroborative evidence of the results given in Table I for apple trees, and will therefore not be separately described.

For the data recorded in Table I, ten-year-old Apple trees growing in the plantations were used. In all cases transverse sections were taken midway between each annual leaf scar of the last five years' growths, and in most cases at other positions also. Branches were not always examined in duplicate as in most cases the sections were made the day following gathering. In all cases where material was regarded as doubtful further branches were gathered and examined, the second observations in such cases were recorded, and the former ones discarded. After the end of July the period between each observation was lengthened.

EXPERIMENTS WITH APPLE TREES BROUGHT INTO THE GREENHOUSE.

On February 2nd, 1926, several trees were brought into a warm greenhouse. Starch was then abundant in the pith, xylem, and cortex, and fairly abundant in the phloem from the base of the five-year-old branches to within 5.0 cms. of the terminal buds. The starch distribution in the 5.0 cms. immediately below the buds was so characteristic that it is diagrammatically shown in Figure 2. The main vascular tissue continued up beyond the lignified pith, and ended in spiral vessels distributed amongst the parenchymatous cells at the base of the bud meristem. This continuation enclosed a region of unlignified pith From January 1st to the end of February the cells of this region appeared free from starch when tested with a solution of iodine in potassium iodide. If, however, the sections were previously cleared in an alcoholic solution of potassium hydroxide the unlignified pith cells were found to contain appreciable amounts of a starch-like substance which stained blue-grey in iodine. The starch content of these cells, and its changes in spring, will be referred to later in this paper. The cells immediately adjoining the lower side of the bud meristem, and the cells of the leaf bases, contained *unmasked* starch throughout the whole year. Thus, except for the 5.0 cms. of stem immediately below the buds, when these trees were taken into the greenhouse on February 2nd starch was abundant in pith, xylem and cortex, and the cambium was in a winter resting condition.

A week after being taken into the greenhouse several spurs and terminal shoots were examined. By this time the tips of the flower buds were just visible between the slightly parted bud scales. Starch had disappeared from the phloem, and partly from the cortex in the one- to five-year-old branches. Otherwise the starch distribution was unchanged. The cambium showed no change.

On February 15th several more spurs and terminals were examined. One of these was a short lateral with a flower truss on one side at 0.8 cms. from the end. The flowers were fully open and several small foliage leaves were partially expanded. At 1.0 cm. below this flower truss vessels were differentiated on the side directly below it, whereas on the opposite side the cambium was swollen but there were no vessels; starch was unevenly distributed in the xylem and phloem; in the xylem it was more abundant on the side where there were new vessels; in the phloem most abundant on the opposite side. Starch was absent from the cortex, and at 1.8 cms. below this flower truss there were no vessels formed although the cambium was in a more advanced state on the side below the truss. At the base of the lateral, starch was abundant in the pith and xylem, present to a small amount in the cortex, and absent from the phloem.

After noting the positions of the flower trusses and short laterals on a three-year-old shoot gathered on February 15th, it was cut up and examined. A line drawing showing its starch distribution and cambial activity is given in Figure 3. Starch disappearance was only complete at a short distance below the terminal buds, and this was the only place where new xylem had been formed. At the point (f) which was immediately below four consecutive developing spurs, the cambium was further advanced and the starch content less than at positions (e) or (d). At the base of this three-year-old shoot the starch content was at a maximum and cambial activity at a minimum. The starch distribution at (f) is significant. It shows a similar unequal starch distribution to that just recorded. These observations along with others of a similar character, and the evidence of localised beginnings of cambial activity—which will be presented later—establish the existence of considerable local activities superimposed upon a general tendency in Spring.

A week later (February 22nd) all the flowers were open and a considerable amount of foliage was developed. Material gathered on this date showed no further xylem formation than that of the week previous. It was, however, (except for the starch sheath) fully depleted of starch. A photograph of a two-year-old shoot along with its starch distribution is shown in Figure 4. This shows an absence of starch down to the base of the three-year-old shoots—in this case over 90.0 cms. below the terminal buds. New xylem was formed throughout the one-year-old shoots, and at (e) in the two-year-old shoots, but not at (d) where the shoot was "bare." Vessels were formed at (e) but not at (f) on the three-year-old shoots. The spurs arising at (d) and (e) invariably had

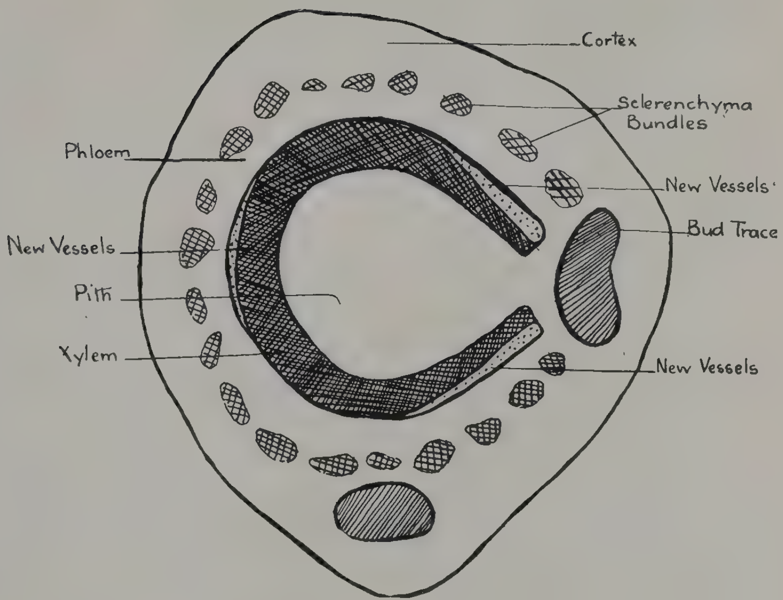


FIG. 1

Diagram showing a transverse Section through a one-year-old apple twig. Note position of new Xylem formation.

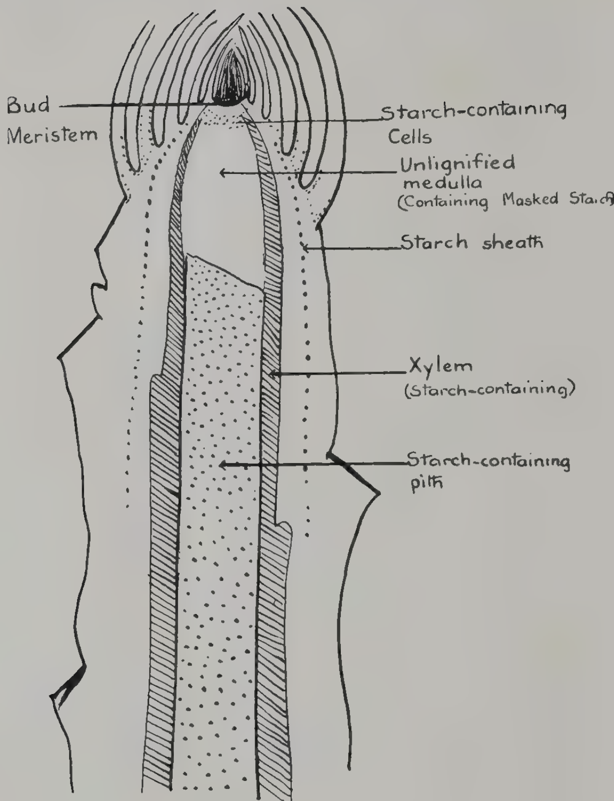
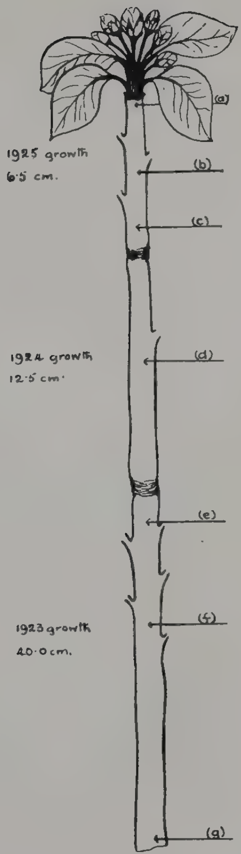


FIG. 2.

Diagram showing tissue distribution and starch content in the stem region immediately below terminal buds during the period of November to January.



(*a*) Starch—Present only in Starch Sheath and Med. Ray Cells of Xylem.

(*a*) Cambium—A single row of vessels is differentiated.

(*b*) Starch—Present in Pith, Starch Sheath and Med. Ray Cells of Xylem.

(*b*) Cambium—Enlarged, 1st stage of growth.

(*c*) Starch—As (*b*).

(*c*) Cambium—As (*b*).

(*d*) Starch—Abundant in Pith, Med. Ray Cells of Xylem, and to a small extent in Med. Ray Cells of Phlœm and Cortex.

(*d*) Cambium—Beginning to enlarge.

(*e*) Starch—Abundant in Pith, almost absent from Xylem and Phlœm.

(*e*) Cambium—Slightly enlarged.

(*f*) Starch—Abundant in Pith. Absent from half Xylem and present in other half, Starch in Phlœm alternates with above.

(*f*) Cambium—Slightly enlarged.

(*g*) Starch—Abundant in Pith, Xylem and Phlœm, Med. Ray Cells and Cortex.

(*g*) Cambium—Beginning to enlarge.

FIG. 3.

Diagram showing starch distribution and cambial activity in a two-year-old apple shoot a fortnight after being taken into the greenhouse.

Note (i) Positions of a complete starch disappearance and of maximum cambial activity.

(ii) The effect of a group of spurs.

(iii) The starch distribution at (*f*).

1925 growth
= 10.5 cm.

1924 growth
= 27.0 cm.

1923 growth
= 50.0 cm.

(*a*) Starch—Absent except in Starch Sheath.

(*a*) Cambium—A row of new vessels differentiated.

(*b*) Starch—Absent except in Starch Sheath. A red brown substance in inner Phlœm cells.

(*b*) Cambium—A row of new vessels down sides of bud traces.

(*c*) Starch—Absent except in starch Sheath. Red brown substance in inner Phlœm Cells.

(*c*) Cambium—New vessels down sides of bud traces.

(*d*) Starch—Absent except in Starch Sheath. Red brown substance in inner Phlœm Cells.

(*d*) Cambium slightly swollen.

(*e*) Starch—Absent except in Starch Sheath. Red brown substance in inner Phlœm Cells.

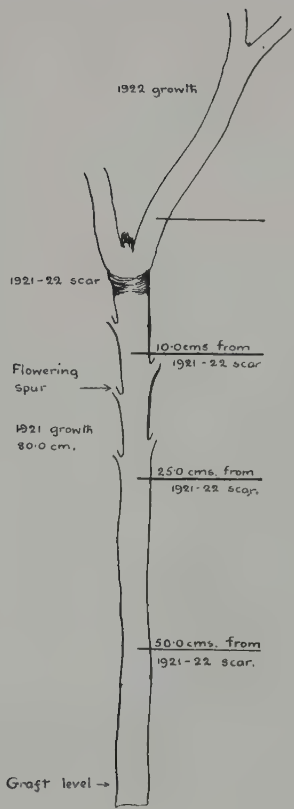
(*e*) Cambium—Vessels beginning to differentiate down sides of bud traces.

(*f*) Starch—Present in isolated Pith Cells and in Starch Sheath.

(*f*) Cambium slightly swollen.

FIG. 4.

Photograph of a two-year-old branch, three weeks after being taken into the greenhouse. Note the sweep out of starch which has occurred since branch shown in Fig. 3, was examined.



Branch shown in Fig. 4 was cut off from here.

Staich—Absent from two outer annual rings. Abundant in pith, cortex, phlœm and inner annual ring.

Cambium—1st stage of growth.

Starch—Absent from three outer annual rings. Abundant elsewhere.

Cambium—1st stage of growth.

Starch—Abundant in pith, phlœm, cortex and Med. Ray cells of xylem.

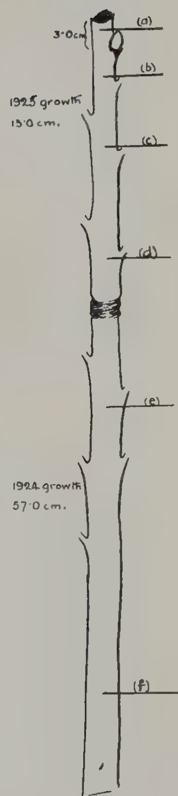
Cambium—Swollen.

Starch—Very abundant in all tissues.

Cambium—Very slightly swollen.

FIG. 5.

Diagram showing the lower continuation of branch shown in Fig. 4. Note starch distribution and content as compared with the part above (Fig. 4), and also the state of cambial activity.



(*a*) Starch—Present only in Starch Sheath.

(*a*) Cambium—Slightly swollen.

(*b*) Starch—Present only in Starch Sheath.

(*b*) Cambium—Swollen and Translucent.

(*c*) Starch—Absent from Pith, small amount present in Med. Ray Cells of Xylem, Starch Sheath, and Cortex.

(*c*) Cambium—A single row of vessels differentiated at one place.

(*d*) Starch—Present in Med. Ray Cells of Xylem, also Cortex, and Starch Sheath.

(*d*) Cambium—A few vessels differentiated down sides of bud traces.

(*e*) Starch—Present in Med. Ray Cells of Xylem, Cortex and Starch Sheath.

(*e*) Cambium—Swollen and translucent.

(*f*) Starch—Considerable amount in Med. Ray Cells of Xylem. Present in Cortex.

(*f*) Cambium—Slightly swollen.

Fig. 6.

Diagram of three-year-old shoot a month after being taken into the greenhouse. Note cambial activity as compared with that of Fig. 4, gathered a week earlier.

a row of vessels fully differentiated in them. Thus, during the week February 15th-23rd there was a complete sweep out of starch from the one- to three-year-old branches. In the main stems cambial activity developed most rapidly in the regions of "massed" spurs.

On February 25th the tree from which the branch shown in Figure 4 was taken, was cut down at the graft level and examined. The parts below the base of Figure 4 are shown in Figure 5, which clearly indicates the basipetal order of starch disappearance. At the base of the four-year-old parts of the branches starch was present in the pith, primary xylem, and inner annual ring, whereas at the base of the five-year-old parts it was present in *all* the annual rings. The relative positions of the most advanced cambial activity should also be noted in Figure 5.

Figure 6 shows the starch distribution in a two-year-old shoot gathered on March 4th (i.e., a month after taking into the greenhouse). By this date the flower petals were fallen. There was little change in the state of cambial activity or starch distribution as recorded on February 25th. This may be partially explained by the fact that this tree was even less vegetatively vigorous than the others. It was observed that there was a close connection between the relative rates of starch disappearance and the development of cambial activity, depending upon whether the proximate buds were vegetative or flower buds. This question will be further dealt with when the data obtained from normal trees are presented.

On March 17th a second tree was cut down. By this time a considerable number of small apples had developed and the foliage leaves were growing rapidly. The disappearance of starch was further advanced, but was far from being complete in the older stems. The cambial state was almost unchanged. On March 17th this experiment was discontinued owing to the temperature conditions of the greenhouse being such as to invalidate any further observations. These observations strongly suggest that there is a relation between the presence of developing buds, cambial activity, and starch disappearance.

THE SEASONAL STARCH CONTENT AND DISTRIBUTION IN ONE- TO FIVE-YEAR-OLD APPLE BRANCHES.

The seasonal variations in starch distribution in the pith, xylem, phloem, and cortex of apple shoots are given in Table I, along with notes of bud break and cambial activity. The table itself should be carefully studied as for the sake of brevity only the salient features are described in the text. The amount of starch present in any given case is difficult to record, but constant practice enables one to decide fairly quickly the *relative* starch content. In Table I the amounts are graded as follows: Absent, Almost absent, Small amount, Fair amount, Fairly abundant, Abundant, Very abundant.

TABLE I.

Showing the Normal Starch Distribution and Cambial Activity in Apple Branches.

Date of Examination and Tissue.	Current year's growth.	One-year-old Shoots.	Two-year-old Shoots.	Three-year-old Shoots.	Four-year-old Shoots.
October 10th, 1925, to January 8th, 1926.					
Pith	—	Abundant		—	—
Xylem	—	,,		—	—
Phloem	—	,,		—	—
Cortex	—	,,		—	—
Cambium		*In Winter Resting Condition*			
January 19th, 1926.					
Pith	—	Abundant	Abundant	Abundant	—
Xylem	—	,,	,,	,,	—
Phloem	—	Almost absent	Almost absent	Absent	—
Cortex	—	,,	,,	Almost absent	—
Cambium		*In Winter Resting Condition*			
Feb. 1st, 1926.					
Pith	—	Fair amount	Abundant	—	—
Xylem	—	Fairly abundant	Fairly abundant	—	—
Phloem	—	Almost absent	Almost absent	—	—
Cortex	—	Small amount	Fair amount	—	—
Cambium		*In Winter Resting Condition*			
March 1st, 1926.					
Pith	—	Fairly abundant	Abundant	—	—
Xylem	—	Fair amount	Fair amount	—	—
Phloem	—	Almost absent	Absent	—	—
Cortex	—	Fair amount	Fair amount	—	—
Cambium		*In Winter Resting Condition*			
March 9th, 1926.					
Pith	—	Abundant	Abundant	—	—
Xylem	—	,,	,,	—	—
Phloem	—	Fair amount	,,	—	—
Cortex	—	Abundant	,,	—	—
Cambium		*Beginning to pass out of Winter Resting Condition*			

TABLE I.—*Continued.*

Date of Examination and Tissue.	Current year's growth.	One-year-old Shoots.	Two-year-old Shoots.	Three-year-old Shoots.	Four-year-old Shoots.
March 16th, 1926.		*Terminal Buds just Beginning to Break.*			
Pith	—	Abundant	Abundant	Abundant	Very abundant
Xylem	—	,,	,,	,,	Abundant
Phloem	—	Fair amount	Fair amount	Fair amount	Fair amount
Cortex	—	Abundant	,,	Abundant	Abundant
Cambium		*Slightly Swollen*	*Passing out of W.R.S.*	*Slightly swollen*	*Slightly swollen*
March 25th, 1926.		*Young Leaves just Visible through Bud Scales.*			
Pith	—	Abundant	Abundant	Abundant	Very abundant
Xylem	—	Fair amount	Fair amount	Fair amount	Abundant
Phloem	—	Almost absent	Almost absent	Almost absent	Small amount
Cortex	—	,,	,,	,,	,,
Cambium	—	*Swollen*	*Slightly swollen*	*Slightly swollen*	*Slightly swollen*
April 8th, 1926.		*Small Foliage Leaves Expanded but Flowers not yet Open.*			
Pith	—	Almost absent	Almost absent	Small amount	Abundant
Xylem	—	,,	Fair amount	Fair amount	Fair amount
Phloem	—	Absent	Absent	Absent	Absent
Cortex	—	Small amount	Small amount	Fair amount	Small amount
Cambium	—	*Swollen (no vessels)*	*Slightly swollen*	*Slightly swollen*	*Slightly swollen*
April 20th, 1926.		*Flowers just Expanding.*			
Pith	—	Absent	Small amount	Small amount	Small amount
Xylem	—	,,	Absent	Small amount (inner ring)	Fair amount
Phloem	—	,, (R.B.).	,, (R.B.).	Absent	Absent
Cortex	—	,,	,,	Small amount	Small amount
Cambium	—	*Some cells vacuolated*	*Swollen*	*Swollen*	*Swollen*
May 5th, 1926.					
Pith	—	Absent	Absent	Absent	Small amount
Xylem	—	,,	,,	Small amount (inner ring)	Abundant in 2 inner rings
Phloem	—	,, (R.B.).	,, (R.B.).	Absent	Small amount
Cortex	—	,,	Small amount	Small amount	Fair amount
Cambium	—	*2 rows of vessels not lignified*	*Cells Vacuolated*	*Swollen*	*Swollen*

TABLE I.—*Continued.*

Date of Examination and Tissue.	Current year's growth.	One-year-old Shoots.	Two-year-old Shoots.	Three-year-old Shoots.	Four-year-old Shoots.
May 17th, 1926.					
Pith	—	Absent	Fair amount	Small amount	Small amount
Xylem	—	,,	Small amount in inner ring	Small amount in inner ring	Small amount in 2 inner rings
Phloem	—	,, (R.B.).	Absent (R.B.).	Absent (R.B.).	Absent
Cortex	—	,,	Small amount	Fair amount	Fair amount
Cambium	—	3-4 *rows of vessels. Inner one partly lig.*	1 *row of vessels. Not lignified*	*Vacuolated Cells*	*Vacuolated Cells*
May 27th, 1926.			*Flowers almost Falling.*		
Pith	—	Absent	Fair amount	Fair amount	Abundant
Xylem	—	,,	Absent	Absent except. inner ring	Fair amount in 2 inner rings
Phloem	—	,, (R.B.).	,, (R.B.).	Absent (R.B.).	Absent (R.B.).
Cortex	—	Small amount	Absent except. St. Sh.	,, except. St. Sh.	Small amount
Cambium	—	6 *rows of vessels.* 4 *lignified.*	3-4 *rows of vessels.* 1-2 *lignified*	2 *rows of vessels.* 1 *lignified*	1 *row of vessels not yet lignified*
June 3rd, 1926.					
Pith	Traces	Small amount	Small amount	Small amount	Fair amount
Xylem	Small amount	Absent	Absent	Absent except. inner ring	Absent except. inner ring
Phloem	Absent	,, (R.B.).	,, (R.B.).	Absent	Absent
Cortex	Absent except. S. Sh.	Small amount	,, except. S.Sh.	Small amount	Fair amount
Cambium	—	11-13 *rows of vessels.* 7-8 *lignified*	6-7 *rows of vessels.* 4 *lignified*	3 *rows of vessels.* 1 *lignified*	2 *rows of vessels.* 1 *partly lignified*
June 10th, 1926.					
Pith	Small amount	Abundant	Abundant	Abundant	Abundant
Xylem	Absent	Fair amount	Fair amount	Fair amount	Fair amount
Phloem	,,	Small amount	Small amount	,,	Small amount
Cortex	Fair amount	Fairly abundant	Abundant	Abundant	Abundant
Cambium	1-3 *rows of vessels lignified*	11-15 *rows of vessels.* 8 *lignified*	8 *rows of vessels.* 5 *lignified*	5 *rows of vessels.* 2 *lignified*	3 *rows of vessels.* 1 *partly lignified*
June 11th, 1926.					
Pith	Absent	Fairly abundant	Abundant	Abundant	Abundant
Xylem	,,	Abundant	Abundant	Fair amount	Small amount
Phloem	,,	Small amount	Small amount	Small amount	,,
Cortex	,, except. S.Sh.	Abundant	Abundant	Abundant	Abundant
Cambium	1-3 *rows of vessels lignified*	14-16 *rows of vessels.* 8-10 *lignified*	7-8 *rows of vessels.* 5 *lignified*	4 *rows of vessels.* 2 *lignified*	2 *rows of vessels.* 1 *lignified*

TABLE I.—*Continued.*

Date of Examination and Tissue.	Current year's growth.	One-year-old Shoots.	Two-year-old Shoots.	Three-year-old Shoots.	Four-year-old Shoots.
June 19th, 1926.					
Pith	Absent	Fair amount	Abundant	Fairly abundant	Abundant
Xylem	Small amount	Fair amount particularly 1926	Almost absent 1924-25. Fair amount 1926	Almost absent from inner ring, abundant in 3 outer rings	Fairly abundant.
Phloem	Absent	Very small amount	Fair amount outer P.	Almost absent	Almost absent
Cortex	Fair amount	,,	Fairly abundant	Small amount	Abundant
Cambium	*Several rows of vessels*	18-20 *rows of vessels.* 12 *lignified*	12-14 *rows of vessels.* 10 *lignified*	8-10 *rows of vessels.* 7 *lignified*	5-7 *rows of vessels.* 4 *lignified*
June 28th, 1926.					
Pith	Absent	Very abundant	Very abundant	Very abundant	Abundant
Xylem	Small amount	Abundant	Abundant	Abundant	,,
Phloem	Absent	Abundant in out. Ph.	,,	,,	Small amount
Cortex	Fair amount	Very abundant	Very abundant	Very abundant	Abundant
Cambium	*Several rows of vessels.*	16-18 *rows of vessels.* 13 *lignified*	11 *rows of vessels.* 8 *lignified*	8 *rows of vessels.* 5 *lignified*	5 *rows of vessels.* 4 *lignified*
July 8th, 1926.					
Pith	Absent	Very abundant	Abundant	Abundant	—
Xylem	Absent	Small amount	Fairly abundant in 2 inner rings Some in 1926 xy.	,,	—
Phloem	,,	Absent	Absent	Small amount	—
Cortex	Absent in starch sheath. Small amount	Fairly abundant	Abundant	Very abundant	—
Cambium	10 *rows of vessels.* 8 *lignified*	20 *rows of vessels.* 14 *lignified*	18 *rows of vessels.* 14 *lignified*	10-14 *rows of vessels.* 10 *lignified*	—
July 19th, 1926.					
Pith	Absent	Very small amount	Abundant	Abundant	Abundant
Xylem	,,	Almost absent	Fair amount	Fair amount	Fairly abundant
Phloem	Very small amount	Very small amount	Very small amount	Very small amount	Small amount
Cortex	Abundant in starch sheath. Small amount	Fair amount	Abundant	Abundant	Abundant
Cambium	10-12 *rows.* 1 *not lignified*	22 *rows of vessels.* 2 *not lignified*	18-20 *rows of vessels.* 4-5 *not lignified*	17-19 *rows of vessels.* 7-8 *not lignified*	15-17 *rows of vessels.* 8 *not lignified*

TABLE I.—*Continued.*

Date of Examination and Tissue.	Current year's growth.	One-year-old Shoots.	Two-year-old Shoots.	Three-year-old Shoots.	Four-year-old Shoots.
July 26th, 1926.					
Pith	Absent	Almost absent	Abundant	Abundant	Abundant
Xylem	,,	Absent	Small amount to absent	Fairly abundant	Fairly abundant
Phloem	Red brown Sbs. only	Small amount	Red brown Sbs. only	Absent (R.B.).	Small amount
Cortex	Fair amount	Abundant	Abundant	Abundant	Abundant
Cambium	14 *rows of vessels.* 1 *not lignified*	24 *rows of vessels.* 2 *not lignified*	18-20 *rows of vessels.* 4 *not lignified*	15-17 *rows of vessels.* 6 *not lignified*	15-16 *rows of vessels.* 7 *not lignified*
Aug. 20th, 1926.		*Terminal Growth beginning to slow down.*			
Pith	Fair amount	Fair amount	Fairly abundant	Abundant	Abundant
Xylem	,,	,,	Fair amount	Fair amount	Fair amount
Phloem	Small amount	Small amount	Small amount	Small amount	Small amount
Cortex	Fairly abundant	Fairly abundant	Fairly abundant	Fairly abundant	Abundant
Cambium	*No unlig. zone*	1 *row of unlignified vessels*	3 *rows of unlignified vessels*	6 *rows of unlignified vessels*	6-7 *rows of unlignified vessels*
Sept. 8th, 1926.					
Pith	Fairly abundant	Fairly abundant	Very abundant	Very abundant	Very abundant
Xylem	Abundant	Abundant	Fairly abundant	Abundant	Fairly abundant
Phloem	,,	,,	Fair amount	Small amount	Small amount
Cortex	,,	,,	,,	Abundant	Abundant
Cambium	*No unlig. zone passing into W.R.C.*	*No unlig. zone*	1 *row of unlignified vessels*	2 *rows of unlignified vessels*	3-4 *rows of unlignified vessels*
Sept. 17th, 1926.					
Pith	Abundant	Very abundant	Very abundant	Very abundant	Very abundant
Xylem	Very abundant	,,	Abundant	Abundant	Fairly abundant
Phloem	,,	,,	Fairly abundant	Fair amount	Small amount
Cortex	,,	,,	Abundant	Abundant	Abundant
Cambium	*In Resting State*	*In Resting State*	*No unlignified zone*	1 *row of unlignified vessels*	2 *rows of unlignified vessels*
Oct. 6th, 1926.			*Terminal Growth Ceased.*		
Pith	Very abundant	Very abundant	Very abundant	Very abundant	Very abundant
Xylem	,,	,,	,,	,,	,,
Phloem	,,	,,	,,	,,	,,
Cortex	,,	,,	,,	,,	,,
Cambium	*In Resting State*	*In Resting State*	*In Resting State*	*In Resting State*	*No unlignified zone*

From October 1st, 1925, to January 8th, 1926, starch was abundant in the pith, xylem, phloem, and cortex of the one- to five-year-old branches. By January 19th a marked disappearance of starch from the cortex and phloem of the above branches had taken place, but there was no observed disappearance from the xylem or pith. Starch remained more or less absent from the cortex and phloem from the middle of January to the end of February, when it re-appeared in considerable quantities. At the beginning of March the starch distribution was similar to that at the beginning of January, but the amounts were less. Terminal buds began to break about March 16th. By the end of March starch had again disappeared from the cortex and phloem of the one- to five-year-old shoots, but not from the xylem or pith, although by the end of the following week (April 8th) it had completely disappeared from the xylem of the one-year-old branches, but not the older ones. By the middle of April the more advanced flower buds were visible. During the period April 8th to the end of May, starch was receding from the tissues down the stem, and except for the starch sheath the one- to three-year-old branches remained free from starch from the middle of April to the beginning of June. The pith of the older branches contained less starch, which showed less seasonal fluctuation as the branches became older. Throughout May and early June when starch was absent from the one- to three-year-old branches, it was also absent from the two outer annual rings of the four- to ten-year-old branches, but was present in the inner rings. The starch content of the inner rings of these older branches was considerably diminished during the above period, but it was never depleted. Thus, the outstanding features of this starch disappearance are (a) it disappears first of all from the phloem, (b) there is a marked disappearance from the phloem in January, which is followed in late February by a temporary re-appearance, (c) it begins in the apical regions and proceeds basipetally, (d) it is complete in the younger branches and incomplete in the older ones.

The first re-appearance of starch in the apple trees under observation was on June 3rd, when several trees showed a small amount in the cortex. This re-appearance was observed throughout the cortex of the one- to seven-year-old branches, and apart from this it is impossible to give any definite order of re-appearance in the several tissues. This first re-appearance of starch in the cortex was followed almost immediately by small amounts re-appearing in the xylem throughout the one- to seven year-old branches. The subsequent rate of deposition, however, was not uniform all over the branches. It was at *first* most rapid in the xylem tissues of the *older* branches, so that by the middle of August their starch content—except the unlignified zone—was approaching the winter amount. During August a small amount of starch was being deposited in the xylem and cortical tissues over the whole of the one- to seven-year-old branches. Towards the end of August, when the elongation of the current season's

growth was ceasing, a rapid starch deposition began in the terminal regions of the young shoots. This deposition worked down the shoots, and was most marked in the phloem. It should also be pointed out here that radial growth ceased in the current season's extension shoots about the same time as elongation growth ceased, and that the cessation of cambial activity then proceeded basipetally with the descending starch accumulation. Thus, there is a marked tendency for starch disappearance, the initiation of cambial activity in spring, the cessation of cambial activity, and the re-deposition of starch in late summer, all to proceed in a basipetal direction. The phloem is outstanding in that it is the first to be depleted of starch in spring and the last to be fully stored with starch in autumn.

The presence of the masked starch in the unlignified pith and the leaf bases of the unfolded buds requires special notice. It was pointed out in the case of trees brought into the greenhouse that these cells contained a masked starch-like substance which was only detectable by an iodine solution after previous treatment of the sections with an alcoholic solution of potassium hydroxide. In the case of normal apple trees it was found that during the period November to March these cells contained appreciable amounts of this masked starch. By the middle of March considerable changes had taken place for then they contained both masked and unmasked starch. By the end of March (i.e., about the time of the initiation of the downward starch disappearance) they had an abundant unmasked starch content. This was apparently due to two factors (a) the unmasking of the previously masked starch, (b) the development of starch within them. At the time of the rapid sweep out of starch from the one- and two-year-old branches the starch of the above cells also disappeared. Two or three rows of cells immediately adjoining onto the lower side of the bud meristem invariably contained starch. From the limited observations made in late summer it appears that the masked starch begins to appear in the unlignified pith at about the time elongation growth begins to slow down.

The occurrence of a substance staining red brown in iodine in the phloem at the time of starch disappearance in Spring, was most marked. Its staining reaction in iodine varied from bright red to blue grey. In some cases it appeared as a fused mass of viscous globules. It was present to a limited extent in the phloem during the temporary starch disappearance in February, but it was most abundant in the medullary ray cells of the phloem just prior to the beginning of active xylem differentiation in Spring. As cambial activity proceeded in spring the substance stained an even brighter red and finally disappeared. It remained absent during June and early July. It appeared again at the end of July which was prior to the setting in of the re-disposition of starch in the tissues. These points are all shown in Table I. It seems clear that it is a transition product of some sort, probably a dextrin-like substance. In view of the alkaline nature

of the phloem tissue, the occurrence of such a transitional body—particularly as a like substance was never observed in the xylem or cortical tissues—is probably important. At present, however, these few observations upon its occurrence are all that is possible.

THE SEASONAL CAMBIAL ACTIVITY IN APPLE TREES.

These observations were made at the same time and on the same material as that used for determining the starch distribution recorded in Table I. In transverse section during Winter the cambium appeared as a layer of regular oblong cells four to six deep. Its natural colour was dirty grey. The beginning of cambial activity in Spring was evidenced by the cambial elements swelling in a radial direction. In 1926 this was first observed on March 9th, which was about the time that the more vigorous buds were increasing in size prior to breaking. The swelling of the cambium took place over all branches up to fifteen years old (older parts not examined), and subsequent to it the outer tissues cortex and phloem) could be easily separated from the xylem cylinder. After this preliminary swelling the cambial zone appeared translucent, and it was much more turgid than during the winter.

The cambium remained in this swollen state for at least a fortnight. Eventually some of the meristematic cells on the xylem side of the cambial layer—though by no means always those directly adjoining the xylem—enlarged in size and developed vacuoles. In many cases the cambium and adjacent tissues remained in this state for some time until the swollen cells enlarged still further, and lost all their contents. After becoming empty the lignification of the vessel walls did not take place for at least ten days. Lignification almost invariably began on the radial walls, as seen in transverse section. When the first row of vessels had been laid down in Spring the cambium appeared as a continuous but irregular tissue five to seven cells deep. It was at this stage that active growth and cell division began. The resulting cambial cells were smaller in size and had thinner walls than the meristematic cells making up the cambium during winter. Rapid and continuous xylem differentiation followed immediately upon this initiation of cell division in the cambium. Thus, the commencement of xylem differentiation in Spring had several distinct phases, the most marked of which was a swollen translucent turgid state of the cambium and the differentiating cells derived from it. During this period there was no active cell division in the cambium ; it was a distinct " lag period."

Although this swelling of the cambium in Spring took place over the whole of the one- to seven-year-old branches, the beginning of active and continuous xylem formation was not so distributed. There were in fact considerable localised beginnings. Generalising from a large number of observations, xylem differentiation began in the terminal regions of all shoots and spurs and developed

downwards towards the roots. Table I shows that on May 5th, 1926, there were two rows of vessels in the one-year-old shoots but none at all in the two-year-old ones. In almost all cases xylem was formed in the spurs and short laterals a fortnight or three weeks earlier than in the parent branch. The initiation of xylem formation showed a marked basipetal order. Up to the middle of July the amount of new xylem formed was always greatest in the one-year-old shoots. Similarly there was always more new xylem in the two- than in the three-year-old shoots. In the bush type of trees used in this work the limit of this downward decreasing amount of xylem was reached in the five- and six-year-old branches. In the standard type of tree this limit may be found in the much older branches. In the single case where a standard plum tree was cut down on June 15th, 1926, there was no formation of vessels in the trunk at eighteen inches above the ground, although there were several rows in the one-year-old shoots. Table I shows that in apple trees vessel formation was at least three weeks later in the four- than in the one-year-old shoots. The downward initiation of xylem formation is hereby established, and it would be very interesting to know the differences that exist between the time of its formation in the one-year-shoots and the bole of a mature standard type apple tree.

The presence of a well developed spur on a short lateral resulted in early xylem formation on the side corresponding to the spur insertion. It was also observed that at the base of the one-year-old shoots the first xylem differentiation was down the sides of the vascular bundles, where they passed from the central stele to the buds. (See Figure 1.) From this position xylem differentiation developed round the whole stem.

The above generalisations regarding the downward initiation of xylem formation requires some qualification. It is clear from Figures 3, 4, and 5 that a group of spurs can cause xylem formation to begin relatively early. That is, a group of them can affect a localised region of the main stem. It was also shown that such a group of spurs could influence the rate of starch disappearance from the same localised region of the main stem. In passing it is interesting to point out that these observations have a distinct bearing upon the concept of the spur being a unit and the factors involved in fruit bud differentiation.

From the beginning of June to the middle of July, the differentiation of new xylem was rapid and continuous. During this period there was a zone of unlignified tissue lying between the cambium and the lignified xylem. This zone was wider in the one- than in the two-year-old shoots, and wider in the two- than in the three-year-old ones. The relative widths of this zone remained approximately constant throughout the growing season. On July 19th it was found to be much narrower in the one-year-old shoots, and during the previous week there had been very little xylem differentiation in them. In the older shoots there was no detectable narrowing of this zone.

During the active growing period the meristematic region was conspicuous because of its small cells filled with dense contents. The layer of dividing cells was never more than three to five cells deep, but from it the cells passed out gradually into the xylem or phloem. The dividing layer of cells was always nearer the phloem than the xylem. Thus during active growth the cambial zone was more conspicuous than during winter, but it was not nearly so well defined. As the season advanced the size of the individual cambial elements became increasingly larger, and the end of cambial activity was easily diagnosed by observing the size and regularity of the cambial elements as compared with those of the active growing period.

It was also observed that during the active growing period starch was never present in the unlignified zone of xylem cells, but that as the zone became narrower the cells began to contain starch. This latter condition was found in the one-year-old shoots about the middle of August but not in the five-year-old ones until the middle of September. Taken together, these observations furnish a criterion of cambial activity in woody stems. Thus, the outstanding features of the cambial activity of apple stems are, (a) Its initial swelling at about the time the buds are swelling prior to breaking, (b) the well marked "lag period," (c) the differentiation of xylem begins at the apical region and works downwards, (d) there is during active growth a zone of unlignified tissue between the cambium and mature tissue, (e) active xylem differentiation ceases in the one-year-old shoots first, then progressively further and further down the stem.

GENERAL SUMMARY.

A study of the normal seasonal changes in starch content in one- to five-year-old branches shows (a) a marked disappearance of starch from the cortex and phloem in January and early February, with a re-appearance in late February. This was followed in May by a complete disappearance from all tissues of one- to four-year branches. (b) The May disappearance began in the phloem throughout the branches, but in the xylem tissues it became rapid in the terminal regions of all shoots and proceeded basipetally. Starch disappearance was three weeks later in the four- than in the one-year-old branches. (c) The disappearance was complete in the younger branches but incomplete in the older ones. (d) The unlignified pith immediately below the bud meristem contained "masked" starch during Winter, which became "normal" about the time of bud swelling in Spring, and subsequently disappeared. (e) A group of short laterals or spurs materially affected a localised region of the main stem. (f) The starch distribution in transverse sections in Spring indicated strong local tendencies. (g) Starch began to re-appear in small quantity in the cortical and xylem tissues about mid-June. When elongation growth slowed down considerably a

wave of starch accumulation began in the apical regions of all shoots and worked downwards.

The seasonal changes in cambial activity were as follows: (a) During Winter the cambium was made up of regular shaped cells four to six deep in transverse section. (b) Subsequent to the first bud swelling in Spring the cambium throughout the parts above ground became swollen and translucent. It remained in this condition for some weeks. (c) The initiation of xylem formation began in the apical regions and worked downwards, there being at least three weeks difference between its initiation in the one- and the four-year-old branches. (d) A group of short laterals affected a localised region of the main stem. (e) During active growth there was always a zone of unlignified tissue to the inside of the cambial layer. (f) Cambial activity ceased in one-year-old shoots about the time elongation growth ceased, but did not cease in the four-year-old branches until a month later. (g) The cessation of cambial activity was preceded by a gradual increase in size of the meristem cells.

There was a difference between the relative rates of starch disappearance and cambial activity in the vegetative and the flowering shoots. In vegetative shoots cambial activity was early and starch disappearance tended to lag behind, whereas in flowering shoots starch disappearance was early and cambial activity tended to lag behind.

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SELF AND CROSS-STERILITY IN FRUIT TREES:*

A SUMMARY OF RESULTS OBTAINED FROM POLLINATION EXPERIMENTS WITH PLUMS, CHERRIES AND APPLES.

The John Innes Horticultural Institution, 1911-1925.

BY M. B. CRANE.

THE experiments made at the John Innes Horticultural Institution ("Self and Cross-Sterility in Fruit Trees," Journal of Genetics, Vols. VII. and XV. and Journal of Pomology, Vol. III.) amply confirm the belief that many varieties of fruit trees are self-sterile and wholly fail to set fruit with their own pollen. It has also been shown that many varieties of cherries and plums, in addition to being self-sterile, fail to form fruits when pollinated with *certain other* varieties, and further, that the varieties involved in this inter-sterility could be assigned to groups within which all self- and cross-pollinations fail. More recently certain plums have been found which fail to set fruit when pollinated by other varieties in the same groups, whereas in reciprocal pollinations their pollen is effective.

Self-sterility is a phenomenon common among plants; but in plants reproduced from seed, pollination from any other plant belonging to the same species is generally sufficient, for they are different individuals. In fruit trees, however, it is essential to remember that the whole of the existing trees of one variety are parts of but one individual, forming as the Americans say one "clone," and that if the variety is self-sterile the pollen from any one tree is quite ineffective on itself, and on any other in the clone. Further complications may hereafter have to be considered, but generally stated—and certainly from a grower's point of view—this is a true representation of the facts.

Since the above publications appeared numerous enquiries have been received from growers. A number have been from prospective planters, but many relate to existing plantations which have failed to fruit satisfactorily, although the trees were in good health and flowered freely. Subsequent correspondence suggested that an epitome of our results would be of value to fruit growers, and the purpose of this paper is to give an account of those aspects of the experiments which are of economic importance. It is noteworthy that all the varieties involved in these inquiries are self-sterile or nearly so, and probably significant that in cherries the variety most frequently mentioned as failing to yield satisfactory crops is Early Rivers.

For various commercial reasons the general practice of growers in recent years has been to plant comparatively few varieties and a large number of each, whereas in old plantations many varieties are invariably to be found. Early

* This paper has already been printed in bulletin form by the John Innes Horticultural Institution.

Rivers is of a comparatively recent origin, and perhaps has come within the new system of planting more than any other commercial cherry. It is self-sterile and already we have found it to be inter-sterile with five other varieties: facts which probably account for these frequent failures.

It is not within the scope of this paper to attempt to refer in detail to such important things as freedom from disease and insect pests, soils, suitable varieties, stocks and the many other essentials for successful cultivation. Many of the problems relating to these aspects of fruit growing have been the subject of extensive investigation, and the results are carefully followed by progressive growers at considerable labour and expense, but the problems connected with pollination and fertilisation are not always so seriously considered. It is, however, abundantly clear from the experiments of many workers in this and other countries, and also from practical observation, that the phenomenon of self and cross-sterility in fruit trees presents a problem of the first importance. Indeed, where trees, though in a healthy condition, fail to yield satisfactory crops, facilities for efficient pollination are probably inadequate, and where this is suspected trees of a known compatible variety should be introduced, or where more convenient, a small proportion of the existing trees could be top-grafted with scions of a suitable variety. Flower-visiting insects should also be considered.

Our fruit trees and many of our small fruits such as raspberries, currants and gooseberries are dependent on the agency of insects—notably bees—for efficient pollination and the production of paying crops. This applies to both self-fertile and self-sterile varieties. It is probable that some plantations are more favoured by the visits of wild bees and other pollinating insects than others. When, however, the labour and expense of pruning, spraying and other cultural operations are considered, and the fact that the presence of hives of bees in plantations may make all the difference between a light and a heavy crop, it is evident that any trouble involved in their maintenance is likely to be well repaid, apart from their utility in providing honey.

Prospective planters will first consider the commercial properties of the varieties they select, but they should also find out which are self-fertile; and if varieties chosen are self-sterile, or only partially self-fertile, they should arrange for others which flower at approximately the same time and are known to be inter-fertile to be interplanted with them. There is no reason why varieties which are self-fertile to a high degree, e.g. Victoria plum, should not be planted in large blocks; but it is worthy of note that as far as we know at present the pollen of self-fertile kinds is always effective on self-sterile varieties and therefore if any self-sterile kinds are grown the self-fertiles might be advantageously interplanted with them. In any case the planting of large areas of a single variety, unless it is known to be self-fertile to a high degree, should be avoided,

also the planting together of varieties which are inter-sterile. Considered at the outset these precautions involve no additional expense, and due attention to such essentials are likely to have a material bearing on future crops. Indeed, they may make all the difference between success and failure.

For efficient pollination there is nothing which necessitates the planting of varieties which are of but little commercial value, neither is it necessary to interplant in such a way that cultural operations are seriously interfered with, e.g. every third row could be planted with a distinct variety.

That bees travel a considerable distance is well known, but they are after nectar and pollen and are not primarily concerned with cross-pollination, and if there is a large block of one variety abundantly supplying their need there is nothing to induce them to do otherwise than work between the hive and this block. The appended lists show that practically all our reliable and heavily cropping plums are self-fertile. This almost suggests that self-fertility is one of the essentials of a commercial plum ; that it is a valuable and desirable character is beyond dispute, but it has been clear throughout the course of these experiments that the majority of the self-sterile kinds have the capacity for high yields, e.g. the Coe's, Jefferson, Pond's Seedling, President, Kirke's Blue and many others have repeatedly carried enormous crops when efficiently pollinated. Therefore, if such kinds were interplanted with suitable mates, *and an abundance of flowering visiting insects assured*, there is no obvious reason why they should not be consistent bearers and carry good crops.

The occurrence of frosts at the time our fruit trees are in flower is a frequent cause of considerable damage, but poor crops are sometimes erroneously attributed to frosts. In cherries and plums there is a well marked initial development which is wholly maternal and independent of fertilisation. With both self-fertile and self-sterile varieties, whether the flowers have been crossed with compatible varieties, selfed, or not pollinated at all, the development is approximately the same during the first three weeks. (See Fig. 1.) After this period the effective selfs and compatible crosses continue to develop, but the un-pollinated and incompatible selfs and crosses begin to shrivel and soon fall.

Observation in the field commonly shows that a large number of young fruits fall at this stage, and it is frequently evident that they have not fallen through the effects of frosts, but owing to lack of fertilisation. The cause of such falls is doubtless due to the absence of flower-visiting insects, or to their enforced inactivity during bad weather, rather than to the effects of frost acting on the fruit. This again demonstrates the potential value of judicious interplanting, and the enormous benefit likely to be derived from bees if they are maintained in orchards and thereby enabled to take full advantage of the bright intervals which frequently occur during a spell of inclement weather. *Fruitgrowers with extensive plantations should regard hive bees as an essential part of their equipment.*

A good deal remains to be done in the determination of the flowering periods of many varieties, and their fluctuations. In the appended lists I have endeavoured to indicate as far as possible those kinds which have proved to be effective pollinisers, with the relative flowering times of plums and cherries recently published by Mr. C. H. Hooper, *Fruit Bulletin*, 10, S.E.A. College, Wye, and in apples with the published records of Mr. F. J. Chittenden, *Jour. R.H.S.*, Vol. XXVII., p. 350.

Among varieties the relative time of flowering varies. A number of the factors involved in this variation are described by R. G. Hatton and N. H. Grubb, *Annual Report East Malling Research Station*, p. 81, 1924. In this report it is shown that the root stock upon which varieties are worked may have a considerable influence on the time the variety comes into flower, e.g. Lane's Prince Albert, gave an average difference of seven days, and in one year ten days, between trees worked on stocks known as types VIII. and IX. and those on type XIII. Hence it seems possible that two varieties which generally in their flowering time overlap sufficiently to allow for effective cross-pollination, might if the earliest of the two to flower was worked on IX. and the other on XIII. have the difference in their flowering time sufficiently widened as seriously to affect the provision for cross-pollination.

I have been informed that in some cherry orchards Governor Wood and Early Rivers flower together in some seasons, whereas in other years one is in advance of the other. This recalls the seasonal fluctuation expressed in the adage:

> If the Ash is before the Oak we're bound to have a soak.
> If the Oak is before the Ash we shall only have a splash.

Fortunately there is considerable overlapping in the flowering periods of the varieties of fruit trees, and with judicious interplanting much can be done to reduce and to guard against these difficulties.

The identity of some of the varieties of cherries used in these experiments is obscure, and it is necessary to refer briefly to the following ambiguities in the material.

Kentish Red " A."—This is not the true Kentish Red. It is self-fertile, has short fruit stalks and is confused with the true Kentish Red which has comparatively long stalks and is self-sterile.

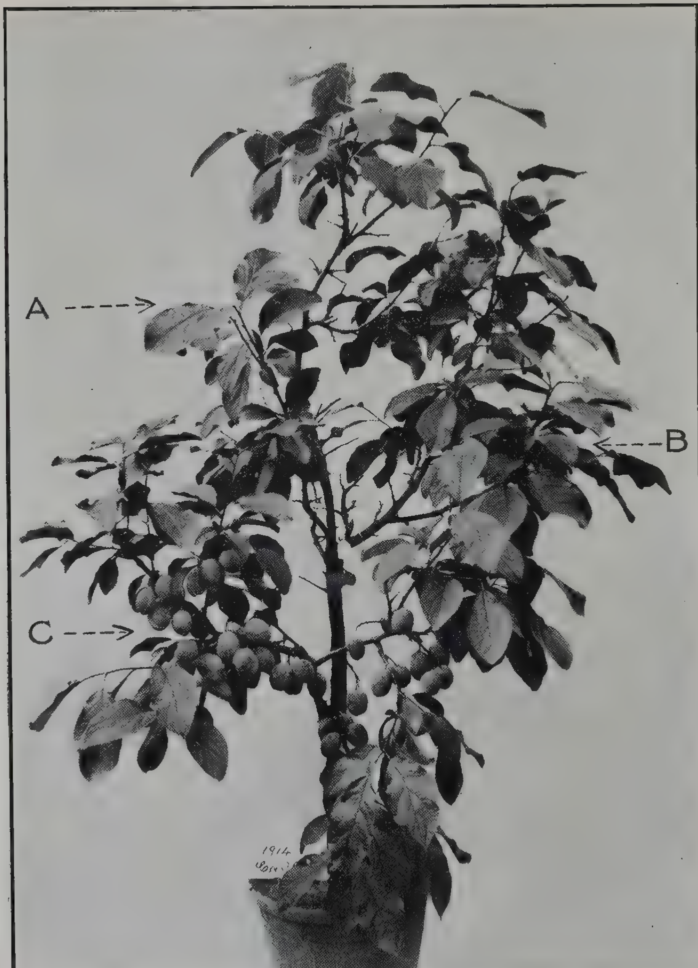
Black Tartarian.—Regarding the identity of this variety there appears to be no general agreement. Under this name we have received three individuals; for reference they were designated " A," " B " and " E." Amongst other salient characters " A " has small stellate flowers and long narrow leaves. " B " and " E " both have large and comparatively broad leaves, and large imbricate flowers. The fruits of " E " are more conical and irregular in shape than those

FIG. 1.

COE'S VIOLET.

A=pollinated with Jefferson. B=self-pollinated. C=pollinated with Bryanstone Gage. Fig. 1, about four weeks after pollination, showing that the fruits pollinated with Bryanstone are larger than the others. Note the primary development of the fruits which were self-pollinated, and cross-pollinated with Jefferson.

Fig. 2.



Coe's Violet.

The same tree as Fig. 1 at a later stage, showing the final result; fruit only on the branches cross-pollinated with Bryanstone Gage. Nothing set with own pollen, nor with the pollen of Jefferson.

Fig. 3.

Big. Napoleon. (Group III.).

A = 258 flowers pollinated with Emperor Francis, no fruit set. B = 34 flowers self-pollinated, no fruit set. C = compatible pollinations, 154 fruits matured from 273 flowers pollinated, *i.e.*, 86 flowers × Guigne de Winkler, 42 fruits set; 37 flowers × Big. de Schrecken, 19 fruits set; 36 flowers × Roundell, 19 fruits set; 60 flowers × Belle de' Orleans, 41 fruits set; 54 flowers × Early Purple Gean, 33 fruits set.

Fig. 4.

Early Rivers (Group I.).

(At top of tree) 490 flowers self-pollinated, no fruit set. 226 flowers × Bedford Prolific (Group I.), no fruit set. 23 flowers × Black Eagle (Group I.), no fruit set. 140 flowers × Knight's Early Black (Group I.), no fruit set. (Bottom of tree) 82 flowers × Late Black Big., 29 fruits set. 25 flowers × Waterloo, 14 fruits set. 60 flowers × Governor Wood, 19 fruits set. 43 flowers × Early Purple Gean, 20 fruits set. 97 flowers × Big. Noir de Schmidt, 43 fruits set. 75 flowers × Guigne de Winkler, 18 fruits set. A few of the matured fruits had fallen from this tree before it was photographed.

From *Journal of Genetics*, Vol. 5, 1925.

of " B." " A " and " B " are reciprocally incompatible and belong to Group I. " E " however, has proved to be compatible with varieties in this group.

The varieties of apples which appear as self-fertile in the appended lists have all eventually set full crops of fruit with their own pollen. Nevertheless in their early years several of them only set a partial crop when selfed, therefore to be on the safe side it is advisable to interplant even these kind of apples.

The following Tables (I. and II.) show the pollinations made between the incompatible plums and cherries and the groups in which they occur. Several cross-pollinations have yet to be made, but it seems safe to predict that any individual will be found to be compatible with any other outside its own group. The large majority of the compatible cross-pollinations have resulted in full crops, thereby proving economically efficient. Some, however, have given comparatively poor results, and it may be that some may prove more efficient than others, but all such cases that we have adequately followed up have eventually given full crops of fruit. Only repetition and continued work will show if any compatible combinations are really more effective than others.

TABLE I

♀ \ ♂		Group I						Group II				Group III	
		Bedford Prolific	Black Eagle	Black Tartarian 'A'	Black Tartarian 'B'	Early Rivers	Knight's Early Black	Big. de Schrecken	Big. Frogmore	Guigne de Winkler	Waterloo	Big. Napoleon	Emperor Francis
Group I	Bedford Prolific	—	—	—	—	—	—	+	+	+	+	+	+
	Black Eagle	—	—	—		—	—	+	+	+	+	+	+
	Black Tartarian 'A'	—	—	—	—	—	—	+	+	+		+	+
	Black Tartarian 'B'	—	—	—	—	—	—	+	+	+	+	+	+
	Early Rivers	—	—	—	—	—	—	+	+	+	+	+	
	Knight's Early Black	—	—	—	—	—	—	+	+	+	+		+
Group II	Big. de Schrecken	+	+		+	+	+	—	—	—	—	+	+
	Big. Frogmore	+	+	+	+	+	+	—	—	—	—	+	+
	Guigne de Winkler	+	+	+	+	+	+	—	—	—	—	+	+
	Waterloo		+					—	—	—	—	+	+
Group III	Big. Napoleon	+			+	+	+	+	+	+		—	—
	Emperor Francis	+	+	+	+	+	+	+	+	+	+	—	—

Table. showing self and cross-pollinations made between incompatible cherries.

— = wholly incompatible (e.g. when Early River's is pollinated by Bedford Prolific, no fruit forms.)

+ compatible combinations.

TABLE II

♀ \ ♂	Group I: Allgrove's Superb	Group I: Coe's Golden Drop	Group I: Coe's Violet	Group I: Crimson Drop	Group I: Jefferson	Group II: Late Orange	Group II: President	Group II: Cambridge Gage	Group III: River's Early Prolific	Group III: Blue Rock
Group I: Allgrove's Superb	—	—	—		—	+		+	+	
Group I: Coe's Golden Drop	—	—	—	—	—	+	+	+	+	+
Group I: Coe's Violet		—	—	—	—	+	+	+	+	
Group I: Crimson Drop		—	—	—	—					
Group I: Jefferson	—	—	—	—	—	+	+	+	+	+
Group II: Late Orange	+	+	+		+	—	—	+	+	+
Group II: President		+	+		+	—	—	+	+	+
Group II: Cambridge Gage			+			.....	.....	.....	+	
Group III: River's Early Prolific	+	+	+		+	+	+	+	.....	+
Group III: Blue Rock			+		+	+	+	+	.....	.....

Table showing self and cross combinations made between incompatible Plums.

— = wholly incompatible, e.g. when Jefferson is pollinated by Coe's Golden Drop or any others within Group I, no fruit forms

..... = partially incompatible, only 2% of fruit sets in these combinations.

+ = compatible.

♀ = The varieties were used as females.

♂ = " " " " " males, *i.e.* as pollinisers

Table III.

CHERRIES.

Self-Sterile.

1. Black Heart, 2, 3, 12, 33.
2. Early Rivers', 6, 12, 15, 22, 24, 25, 31, 33.
3. Elton, 1, 5, 4, 10, 12, 14, 15, 23, 30, 33, 37.
4. Emperor Francis, 2, 3, 5, 6, 7, 10, 11, 12, 22, 23, 24, 25, 27, 31, 33.
5. Turkey Heart, 4, 11, 15.
6. Governor Wood, 2, 4, 5, 7, 9, 10, 11, 12, 13, 19, 20, 21, 26, 28, 29, 31, 33.
7. Knight's Early Black, 6, 12, 13, 23, 27, 31, 33.
8. Early Purple Gean, 2.
9. Black Eagle, 12, 13, 16.
10. Black Tartarian, B, 3, 13, 19, 27.
11. Bedford Prolific, 3, 5, 6, 8, 12, 13, 20, 22, 24, 27, 28, 31, 33.
12. Big. Frogmore, 1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 16, 20, 21, 24, 25, 27, 29.
13. Big. Napoleon, 2, 6, 7, 8, 11, 12, 16, 18, 21, 23, 24, 26, 30, 31, 33.
14. Monstreuse de Mezel.

Self-Sterile.

15. Waterloo, 16.
16. Amber Heart (Kentish Big.), 13, 19, 30.
17. Florence, 16.
18. Kentish Red, 40.
19. Big. Noir de Guben, 2, 6, 12, 22, 23, 28, 33.
20. Noble, 4, 5, 6, 10, 11, 12, 29, 31.
21. Belle d'Orleans, 2, 13, 26.
22. Belle de St. Tronc, 7, 11, 13, 19, 23.
23. Big. Jaboulay, 2, 4, 11, 12, 7, 18, 19, 22, 28, 33.
24. Late Black Big., 4, 6, 11, 12, 15, 22.
25. Big. Noir de Schmidt, 2, 4, 6, 8, 12, 20, 23, 24.
26. Black Tartarian " A ", 6, 20, 24.
27. Black Tartarian " E ", 6, 13.
28. Bohemian Black, 2, 4, 19, 24, 29, 41.
29. Géante d'Hedelfingen, 17, 28.
30. Guigne d'Annonay, 2, 4, 18, 33.
31. Guigne de Winkler, 2, 4, 6, 7, 8, 9, 10, 11, 13, 23, 24, 26.
32. White Heart, 2, 18, 33.

Self-Sterile.

33. Big. de Schrecken, 1, 2, 3, 4, 5, 6, 7, 11, 13, 20, 21, 22, 23, 26, 29, 30.
34. Toussaint.

Partially Self-Fertile.

35. May Duke, 18, 40.
36. Archduke.
37. Royal Duke.
38. Empress Eugenie, 11.

Self-Fertile.

39. Flemish Red.
40. Morello.
41. Kentish Red " A."
42. Late Duke.
43. Wye Morello.

According to Mr. Hooper's Bulletin Nos. 1-6 are early, 7-17 mid-season, and 18-20 late flowering varieties.

The relative flowering period of the remainder has not been ascertained.

In this and the following Tables the numbers, following the names of the varieties indicate those varieties which have proved to be effective pollinisers, e.g., Black Heart Cherry has produced good crops when pollinated with number 12. Big. Frogmore 3. Elton, etc.

N.B.—Prospective planters are advised to satisfy themselves that the varieties they choose for planting together flower approximately at the same time.

TABLE IV.

PLUMS.

	SELF-FERTILE.	PARTIALLY SELF-FERTILE.	SELF-STERILE.
EARLY FLOWERING VARIETIES.	1. Prince of Wales. 2. Early Mirabelle. 3. Guthries' Late. 4. Monarch. 5. Reine Claude de Bavay. 6. Dennistons' Superb. 7. Early Transparent.	20. Blue Rock, 1, 25, 33, 35, 38, 40. 21. Rivers' Early Prolific, 1, 7, 8, 10, 14, 25, 31, 33, 35, 36, 38, 40.	30. Late Orelans, 8, 11, 12, 21, 22, 26, 32, 39, 40, 46. 31. Allgroves' Superb, 1, 21, 25, 36, 40. 32. Coe's Golden Drop, 1, 4, 6, 7, 8, 9, 17, 20, 21, 22, 23, 25, 30, 36, 37, 38, 39, 40, 41, 42, 46, 48. 33. Coe's Violet, 10, 13, 21, 25, 26, 29, 38, 40, 43. 34. Crimson Drop, 37, 43. 35. Jefferson, 4, 7, 8, 21, 26, 30, 36, 37, 39, 40, 46, 49. 36. Comte d'Althan, 4, 7, 21, 25, 32, 33, 35, 38. 37. Old Greengage, 10, 34, 35, 39, 42, 43, 46. 38. President, 14, 21, 25, 32, 33, 35.
MID-SEASON VARIETIES.	8. Giant Prune. 9. Golden Transparent. 10. Victoria. 11. Farleigh Damson. 12. King of the Damsons. 13. Pershore. 14. White Magnum Bonum.	22. Early Orleans. 8. 23. Reine Claude Violette (Purple Gage). 24. Belgium Purple, 33. 25. Cambridge Gage, 7, 21, 28, 33. 26. Cox's Emperor, 8, 21, 35, 45, 46. 27. Prince Engelbert.	39. Bryanstone Gage, 21, 35, 37, 49. 40. Late Orange, 7, 21, 25, 31, 32, 33, 35, 36. 41. Wyedale, 21, 32, 35, 42. 42. Early Greengage, 10, 21, 26, 29, 37, 39. 43. Kirke's Blue, 25, 33, 37, 38, 40. 44. Old Transparent, 46.
LATE FLOWERING VARIETIES.	15. Czar. 16. Goliath. 17. Oullin's Golden Gage. 18. Gisbornes'. 19. Belle de Louvain.	28.*Early Favourite. 29.*Frogmore Damson, 8, 11, 26, 32, 45. * relative flowering times not ascertained.	45. Pond's Seedling, 7, 10, 21, 26, 44, 46, 48. 46.*McLaughlin's Gage, 8, 16, 23, 26, 33, 35, 45. 47.*Primate, 9. 48.*Yellow Magnum Bonum, 14, 20, 30, 32, 38.

Table V.

APPLES.

Partially Self-Fertile.

4. Ribston Pippin.
5. Norfolk Beauty.
6. Sturmer Pippin, 11.
9. Bismarck.
10. Lord Hindlip, 11, 22, 27.
11. Cox's Orange Pippin, 2, 6, 15, 22, 23, 24, 25, 26, 35, 38.
12. Duke of Devonshire.
13. Beauty of Bath, 1, 5, 11, 38.
14. Blue Pearmain.
15. Worcester Pearmain, 11, 22.
16. Lady Sudeley, 11.
17. Lord Derby,
19. Lane's Prince Albert, 11, 22.
20. King of the Pippins, 30.
21. Grenadier.
24. Annie Elizabeth, 11, 19, 22.
26. Newton Wonder, 19.
27. Northern Greening, 22, 29.
30. Encore, 32.
31. Golden Russet.

Partially Self-Fertile.

32. King's Acre Pippin, 30.
33. Winter Ribston, 30. (Orleans Reinette).

Note.—Mr. F. J. Chittenden (Jour. R.H.S., XXXVII., p. 350) gives the approximate order of flowering as represented by numbers 1-29.

e.g. Nos.	1-4	early flowering,
	5-15	2nd early ,,
	16-24	mid-season ,,
	25-29	late ,,

The flowering period of Nos. 30-38 has not been ascertained.

Self-Fertile Varieties.

1. Golden Spire, 11, 13.
2. Duchess of Oldenburg, 1, 11, 17.
3. Stirling Castle, 11.
7. Washington.
8. Red Winter Reinette.
18. Cellini.
22. Bramley's Seedling, 11, 24.
23. Crimson Bramley, 11, 15.
34. Baldwin.
35. Coronation.
36. Antonowka, 15, 25, 35.
37. St. Everard, 13, 32.
38. Rev. W. Wilks, 13.

Self-Sterile Varieties.

25. Gascoyne's Scarlet, 5, 11.
28. Brownlee's Russet.
29. Royal Jubilee, 19, 27.

REVERSION OF BLACK CURRANTS.

I. SYMPTOMS AND DIAGNOSIS OF THE DISEASE.

By J. AMOS and R. G. HATTON.
East Malling Research Station, Kent.

Introductory.

There is evidence from a report by Professor Ritzema Bos, of Holland (1), that at least some of the symptoms of the trouble which is now commonly called "Reversion" in Black Currants were noted in Holland and Germany more than twenty years ago. It is apparently not until 1912 that horticultural literature in England bears witness to its existence. These early references show that the nature and extent of the trouble were not then fully realised.

The report of a meeting of the Scientific Committee of the Royal Horticultural Society on July 16th, 1912 (2) reads as follows :—

"Mr. Charles Pearson sent shoots of black currant Boskoop Giant to illustrate a variation which had suddenly arisen in several localities.

"In the sport the leaves become very much more dentate and the bushes fail to fruit. Sometimes only a portion of the bush is so affected, but frequently, the whole; and in one plantation 50 per cent. of the bushes showed the variation. The Committee would welcome any observations that would throw light upon the phenomenon. It has been suggested that possibly hard pruning may have brought about the result, but there is no record so far of recovery to the normal form."

A month later it was reported (3) that the trouble was common amongst the Worcestershire growers, and several theories as to the causes of this "throw back" in Black Currants were suggested.

Contemporaneously, a correspondence in the *Gardeners' Chronicle* (4) bore witness to the existence of the disease in widely different parts of the country, and particularly in the variety Boskoop Giant. However, it was said to be "uncertain if this may be considered a new disease, or if it is merely that more attention is now paid to such matters," and the theory was advanced that the trouble was merely due to the "upsetting of the normal course of pruning and bud development," and that the entire removal of the old branches, and the resultant forcing up of young growth from below might overcome the reversion.

Southern Grower was writing (5) "Reversion is not infectious, but infected bushes never recover" and again "the case appears to be simply one of reversion to the wild state," and by 1914 he was reporting (6) "Wherever visits have been paid to fruit farms on which Black Currants are grown, more or less reversion towards the wild state has been found usual."

The notebooks of Captain R. Wellington, the first Director of the East Malling Research Station, testify to the fact that Black Currants "running wild" were under his observation in Kent plantations in 1913, and his tracings of the abnormal leaves are still preserved there. The "nettle-headed" growths are also described in them; indeed, not a few of the first plots of black currants established at the Station for observation purposes were of these so-called "wild" strains.

Despite this comparatively early recognition of the disease and its apparent widespread distribution, practically no progress was made in those days towards a more exact knowledge of the trouble because there was no commonly accepted diagnosis. Indeed any manifestations of "nettleheadedness" or non-cropping, which it is now recognised may be due to several different causes, were cited as cases of Reversion.

I.—Possibility of Diagnosis of Reversion from Leaf Characters.

Mr. A. H. Lees, in his paper on "A method of identifying Reversion of Black Currants" (7), by attempting to fix a quantitative basis for its recognition, first opened the door to a real advance in our knowledge of the subject. Although it soon became evident that the standard originally set up by him required considerable modification in view of the special characteristics of individual varieties, this paper describing the relative number of sub-main veins and uninnervated points (i.e., teeth without veins) of the terminal or central lobe of healthy and reverted leaves respectively, lays down a valuable method of identification capable, in intelligent hands, of universal application. Leaflet No. 377 of the Ministry of Agriculture, (8) revised in February, 1925, clearly summarises Lees' early conclusions, with certain modifications, and presents the essential points as follows:—

> "If less than five (submain veins) are present (on each side of the main vein in the central lobe of the leaf) the leaf is reverted, if five or more the leaf is probably normal."

With regard to the marginal serrations or teeth which do not receive these sub-main veins, and which Lees describes as "uninnervated points" the leaflet in question says:—

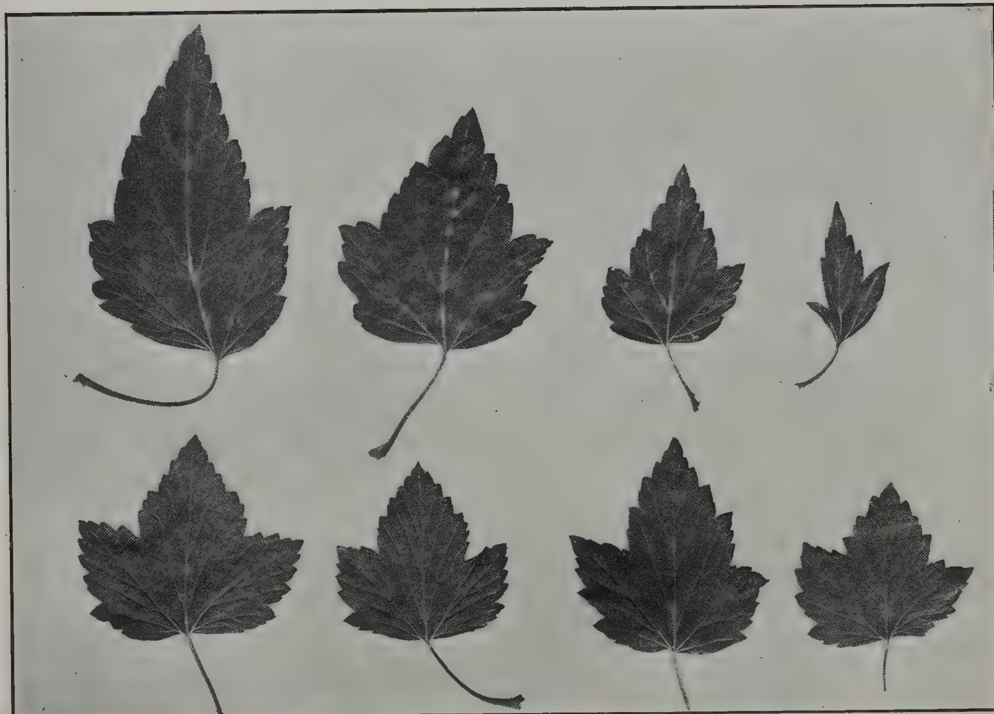
> "If the margin (on both sides of the central lobe) is finely toothed, and if from four to eight of these teeth do not each receive a submain vein, the leaf is almost certainly normal. If, however, this portion of the margin is coarsely toothed, and if less than four of the teeth do not each receive a sub-main vein, the leaf is reverted to some degree."

PLATE I.

Normal Leaf of French Black. Note the number of veins and teeth in the terminal lobe.

Reverted Leaf of French Black. Compare the number of veins and teeth in the terminal lobe.

PLATE II.



Typical Axillary Leaves of Normal French Black. (above.)
Spur leaves from same bush showing wide variation in shape and veining. (below.)

The diagrams reproduced from Lees' paper in this leaflet make the position abundantly clear, but two photographs are added in the present paper which show the actual condition of affairs. (See Plate I.)

This method of detecting reversion, by concentrating upon particular symptoms such as the numbers of submain veins of the central lobe and the number of uninnervated points, when considered in conjunction with the normal characters of the healthy leaf for each variety, does indeed appear to be fool-proof. However, in order to use the method with ease and certainty, it is essential to have a knowledge of a normal black currant branch and also to appreciate the small but important differences which distinguish one variety from another.

Characters of Normal Shoot and Foliage. A normal black currant branch in June will almost universally consist of one or more leafy vegetative shoots, which have developed from buds formed in the previous season, and situated chiefly towards the top or the base of the previous year's wood. These are the shoots on which to concentrate in order to study either normal or abnormal characters. The rest of the branch will consist in the main of short lateral growths and fruiting spurs, which have arisen from the buds of the previous season situated on the middle portion of the previous year's wood. The leaves on these spurs and on the short laterals are very different in character from the fully developed leaves on a strong growing shoot, and reliance on them has not infrequently misled the grower into thinking that he has reversion. Lastly, not infrequently small leaves—so-called "axillary" leaves—develop at the bases of the larger leaves. These, even on a perfectly healthy branch, are very irregular in form and often unnecessarily arouse suspicion. The grower can safely ignore all these types of subsidiary leaves entirely in endeavouring to detect the disease.

Whilst therefore it would be a very difficult matter to fix an average normal healthy standard to include *all* leaves, it is a comparatively simple matter to do so, as Lees suggested, for the fully developed leaves on the main growths alluded to above. In the summer of 1921 large collections of spur and axillary leaves taken from healthy and reverted bushes of four varieties were made, examined and measured. Although the collection of the spur leaves from reverted bushes contained a considerable proportion of deficiently veined examples, yet, on the average, the difference between these leaves and similar ones from normal bushes was certainly not marked. The axillary leaves collected from the two sources showed no constant differences at all. The following table shows the actual counts and measurements made on 100 leaves from each source for Boskoop Giant and Baldwin, whilst Plate II. shows typical axillary and spur leaves collected from healthy French Black.

TABLE I.

Comparison of Subsidiary Leaves from Healthy and Reverted Bushes.

	Average No. submain Veins.		Average No. of Teeth.		Breadth across basal lobes in mm.		Length from Apex to Base.	
	Normal.	Revert.	Normal.	Revert.	Normal.	Revert.	Normal.	Revert.
"Spur" Leaves :								
Boskoop Giant ..	6.7	6.3	7.7	6.6	15.0	15.7	18.7	19.4
Baldwin	6.6	6.0	7.8	6.0	14.8	12.2	18.3	17.0
"Axillary" Leaves :								
Boskoop Giant ..	3.2	2.7	2.0	0.7	8.8*	8.1	10	9.6
Baldwin	3.1	3.8	1.2	1.7	8.9*	9.3	10	11.3

* Greatest breadth was here found more practicable.

It is obvious that, generally speaking, these axillary and spur leaves vary too much to justify further consideration for diagnostic purposes.

II. The Characteristic Veining and Serration of Leaves on the Normal or Healthy Shoot.

On examining the leaves of any normal wood-shoot of the current year, it will be found that the actual numbers of submain veins and serrations (teeth) in the central lobe varies from leaf to leaf. Generally speaking, however, this variation is not haphazard, but appears to bear a relationship to the position of the leaf on the shoot, and, probably therefore, to the period of growth. Lees (9) referred to this in 1922 in connection with a single shoot of an unnamed variety, and later the matter was checked at East Malling on ten or more shoots of each of the four chief varieties. It was found that the same phenomenon existed throughout.

The leaves at the base of the shoot, i.e. those formed at the beginning of the year's growth, possessed the greatest number of these submain veins and teeth. There was a marked falling off in number in the leaves situated towards the central part ot the shoot, i.e. those formed in the period of maximum growth in length of the shoot. In leaves attached towards the top of the shoot, i.e. those developed during the period of late growth, the submain veins and teeth again became distinctly more numerous.

This is well shown in the following table, which gives the average number of submain veins and teeth on *one* side of the main vein of the central lobe of

successive leaves in ten shoots of each of five different varieties. The counts were made upon these normal shoots between July 1st and July 6th.

TABLE II.

Position on Shoot.	Baldwin.		Boskoop.		Goliath.		French.		Seabrook.	
	Veins.	Teeth.	Veins.	Teeth.	Veins.	Teeth.	Veins.	Teeth.	Veins.	Teeth.
Apex 1	6.9	9.6	6.5	10.7	6.1	10.1	6.0	7.7	6.4	9.4
2	6.4	10.2	6.6	11.0	6.1	11.6	6.2	8.1	6.6	10.4
3	6.3	9.2	6.3	10.2	6.1	11.0	5.8	7.5	6.2	10.2
4	6.3	8.7	6.3	11.4	6.1	10.6	5.7	7.3	6.3	10.3
5	6.3	7.7	6.3	9.3	6.1	11.0	5.4	7.2	5.9	9.7
6	6.2	7.3	6.1	9.8	5.9	11.3	5.5	5.2	5.7	7.3
7	6.0	8.5	6.3	9.0	6.0	11.1	5.0	4.8	5.8	8.0
8	5.8	7.9	6.3	10.9	6.2	11.5	5.1	5.8	5.7	6.8
9	6.3	9.9	6.6	11.8	6.4	11.5	5.3	7.1	5.8	8.1
10	6.1	10.6	7.0	12.6	6.3	11.5	5.6	8.4	6.1	8.9
11	6.3	11.2	7.2	12.8	6.3	11.0	6.0	9.4	6.1	8.5
12	6.6	12.9	7.3	14.0	6.6	12.4	6.2	11.1	6.3	10.2
13	7.1	13.0	7.1	11.8	6.8	13.3	7.1	12.7	6.7	11.3
14	7.6	13.3	7.0	11.6	6.8	13.3	7.1	9.5	6.9	11.0
15	7.4	11.2	—	—	7.1	11.6	6.9	6.9	7.3	10.6
16	7.0	8.8	—	—	7.2	13.4	6.9	7.3	—	—
17	6.8	—	—	—	—	—	6.6	—	—	—
Base 18	6.8	—	—	—	—	—	—	—	—	—

The table also gives a very fair picture of the average number of both submain veins and teeth which are likely to be found on the five different varieties in common use. It is clear that whilst healthy leaves of the varieties Boskoop Giant, Goliath and Baldwin rarely, if ever, have fewer than six submain veins, French Black, and to a lesser extent Seabrook's, have many normal leaves with only five submain veins on each side. Further, looking at the number of points, Goliath and Boskoop average very many on the one hand, whilst French at the other extreme illustrates the minimum that may be expected on normal leaves.

Counts and measurements made on further lots, ten shoots of each variety, taken from much older bushes, confirmed the above observations, but showed that the range of variation between the two extremes may be even greater, normal leaves of French Black frequently being found to have only four uninnervated points or teeth, and not infrequently five submain veins on one side and four on the other.

Thus, whilst all these varieties, under normal conditions, come very near to complying with Lees' standard as regards the number of submain veins, yet, in regard to uninnervated points, the French group rarely has *many* ; and leaves of varieties in this group with as few as four must not be regarded as suspect. Hence when rogueing, it is necessary to approach the task with a clear idea in one's mind of the normal leaf characters of the particular variety being dealt with. The above table gives such a picture for the varieties therein included.

III. The Characteristic Veining and Serration of Leaves on the Reverted Shoot.

Since it is convenient to fix attention on that portion of the shoot bearing leaves in which the number of submain veins and points actually falls below the normal average, Lees directed attention to the middle portion, the May and June growth, where on the reverted shoot the leaves have submain veins less than five aside, and the points are very few. As a matter of fact, however, it would appear that even the basal and terminal leaves on the reverted shoot have correspondingly fewer submain veins and points. For instance, if the normal average number of submain veins for the healthy basal leaves of French is 6.9, that for the reverted basal leaves of the same variety is 5.7. This is quite well illustrated in columns 2 and 4 of the following table, which shows the average number of submain veins and teeth for one side of the main vein of the central lobe of successive leaves in normal, reverted and "false" reverted examples of the variety French. (For detailed description of "false" reversion, see Section IV. below.) Ten shoots were examined in each case on July 10th, 1925.

Table III.

Position.		Normal.		Reverted.		False Reverted.	
		Veins.	Teeth.	Veins.	Teeth.	Veins.	Teeth.
Apex	1	6.0	7.2	5.0	3.7	6.0	7.7
	2	5.7	7.4	4.4	5.1	5.9	7.9
	3	5.1	6.7	4.0	4.4	5.2	7.2
	4	5.0	6.1	3.5	3.0	4.7	6.0
	5	5.3	6.0	3.5	2.8	4.2	4.7
	6	5.8	6.7	3.9	3.3	4.3	5.1
	7	5.8	8.2	4.3	3.4	4.1	5.0
	8	6.1	8.8	4.5	4.4	4.2	5.7
	9	6.5	10.1	4.8	5.9	4.1	5.1
	10	6.5	10.7	5.6	6.1	3.9	4.5
	11	6.2	8.4	5.5	5.5	3.4	4.8
Base	12	6.9	7.7	5.7	4.6	3.2	3.0

The same characteristic features are similarly contrasted in Plates III. and IV.

IV. Production of Abnormal Foliage on Healthy Bushes. "False" Reversion.

The counting of submain veins and teeth is a process which becomes almost automatic as the eye becomes trained, but whilst it is, generally speaking, an admirable criterion for health or disease, there are unfortunately certain conditions under which the growth of the plant is upset and which lead to the production of anomalous foliage showing very similar manifestations to those of reversion.

PLATE III.

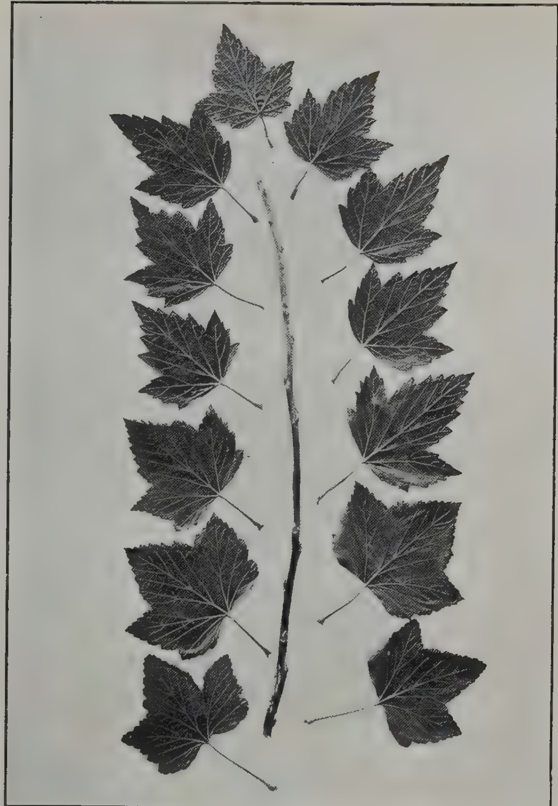
Normal Shoot of French Black.

Terminal lobes five veined throughout.

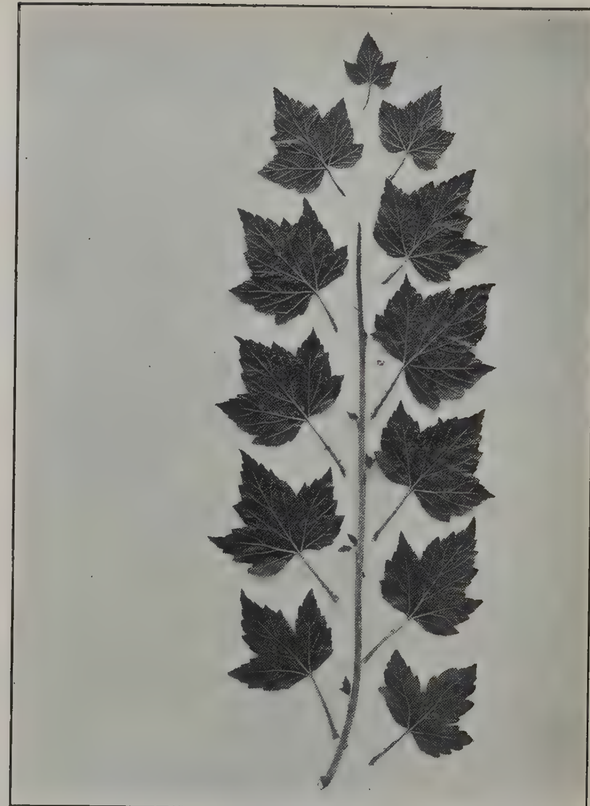
Early Stage of true "Reversion" on French Black.

Terminal lobes of six basal leaves showing normal veining.
Seventh to tenth leaves show only four veined leaves.

PLATE IV.



Advanced Stage of true "Reversion" on French Black. Sixth to eleventh leaves show characteristic deformation.



Shoot of French Black showing "False" Reversion. Terminal lobes of basal leaves show only four veins.

For instance, the tip of a growing shoot may be accidentally damaged, and in consequence, one or more of the lateral buds below, which would normally have remained dormant until another season, is forced into growth. Many of the leaves on a shoot arising from such a bud will be found to be deficient in submain veins and teeth. This phenomenon is referred to by Lees as "temporary" reversion (9), but possibly the term "false" reversion would better emphasise the fact that such shoots are never really diseased, i.e. reverted.

From the point of view of the practical man when rogueing his bushes, the occurrence of this symptom in presence of obvious damage will, in the great majority of cases, be sufficient to reassure him when once he knows of its existence. There are, however, borderline cases in which it would be difficult to decide between true and false reversion, if the importance of the relative positions of the leaves, already discussed, was not clearly understood. In false reversion, it is the *basal* leaves which are deficient in submain veins and teeth, and as the shoot advances in growth, the later formed leaves tend to arrive at the normal condition in regard to submain veins and teeth. In true reversion, on the other hand, the basal leaves are above the limit of danger laid down, i.e. they have five or more submain veins, and it is the *later formed leaves* which manifest the shortage. Columns 6 and 7 (False-Reverted) in Table III. in comparison with columns 2 and 4 clearly illustrate this point. Plates III and IV show the three types of shoot.

Detailed examination such as this must therefore serve as a final court of appeal in doubtful cases, though in actual practice these will obviously be few. One further important fact, however, must be mentioned. It is possible to cause the symptoms of false reversion to appear upon a shoot of a genuinely reverted bush by purposely damaging the shoot, though it is interesting to note that in a case of this kind the leaves are apparently more deficient in submain veins than are those on a similar shoot from a healthy bush under comparable conditions. For instance, whilst the false reversion on a healthy bush may start with three or four submain veined leaves, the false reversion on a reverted bush will probably start with leaves having only one or two submain veins. This is more a matter of scientific interest than of practical import, because the undamaged parts of the truly reverted bush would tell their own tale, and it is most unlikely that the practical man would pass over such a bush because of an occasional damaged shoot showing symptoms similar to false reversion.

V. Causes of False Reversion.

In view of the fact that the grower is likely not infrequently to meet with symptoms of false reversion, it may be worth while describing the most common circumstances under which they manifest themselves. The chief causes may be summarised under four heads :—

(a) *Damaged Growing Tips.* False reversion is most easily produced deliberately by the removal, during the summer, of the tip of any growing healthy shoot. This results in forcing into growth those lower lateral buds which would normally have remained dormant during the current season. The leaves on the shoots from these buds manifest the typical symptoms of false reversion already described. In the spring of 1924, a series of experiments was carried out with the object of determining (i) how far this false reversion could be caused at will, (ii) how far it depended upon the time at which the injury took place and (iii) to what extent the position of the injury upon the bush was of importance. The variety used was French Black. A "control" set of shoots, twenty-four in all, distributed over ten healthy bushes, had their terminal buds cut out on March 3rd, whilst the plants were still quite dormant. The resulting lateral growths produced perfectly normal foliage, and subsequently behaved normally with regard to fruiting. In May, twenty shoots each, on five healthy bushes, had their growing tips pinched off, and further lots were similarly treated in June and July. The May and June series, without exception, produced new lateral growths with leaves showing typical false reversion, but a year later, in June, 1925, these shoots had nothing but normal foliage, and produced fruit. The lateral buds in the July series remained dormant in that season but in the following year developed laterals with quite normal foliage.

In a second series of experiments half the length of the shoot was removed at three similar intervals instead of merely pinching off the growing tips in each case. The results were similar to those in the first series, although the new shoots produced were much more vigorous.

The shoots in a third series were cut at similar intervals to within an inch of the base of the new growth. In all cases new lateral growths showing false reversion were produced; even those so treated in July gave very weak new growths with small leaves deficient in submain veins.

The three series of experiments were repeated in 1925 but with a smaller number of shoots in each case and the first year's results were confirmed.

The experiments described establish the facts that, in order to produce the symptoms of false reversion, the damage must take place during the active growing season and that identical symptoms are produced in the leaves of growths from very different parts of the shoot as a result of such damage. They also show that these symptoms, caused at will, are of no consequence to the plant's subsequent behaviour, since the shoots, without exception, afterwards returned to normal growth and fruiting.

Damage of the sort indicated occurs naturally not uncommonly, both in the plantation and the nursery, as a result of the normal processes of cultivation, aphis damage, etc. Numerous individual shoots showing these symptoms as a

PLATE V.

Fig. 1. Typical case of "False" Reversion, caused by removal of growing tip, and consequent forcing of lateral buds into growth.

Fig. 2. Another case of "False" Reversion resulting from natural divided growth. Note typical four veined leaves at base of new growths.

PLATE VI.

Fig. 1. "False" Reversion, resulting from extreme hard pruning, forcing poorly developed buds into growth, on French Black. Note four veined coarsely serrated leaves from base.

Fig. 2. Plant of same variety which showed similar symptoms the previous year and has now returned to normal foliage. The "running off" of blossom is due to late transplantation for photographic purposes.

result of such checks to growth have been found in the plantation and nursery at East Malling and have been kept under observation, with the result that, without exception, these plants returned to a normal condition in the following season. In July, 1923, ten shoots of Boskoop Giant, six of French and five of Seabrook's, which appeared to have been damaged, were marked in the plantation and were subsequently selected for cuttings. These cuttings were left in the nursery until June 16th, 1925, when they were all closely examined and pronounced normal. A similarly damaged bush of Seabrook's Black, found in the nursery, gave the same result. Plate V., Fig. 1, shows a typical case of false reversion resulting from a damaged growing tip.

(b) *Divided Tips.* Closely allied to, if not identical with, damaged tips, are those cases in which the cause of the check is not so obvious. For instance, some shoots instead of ending in a single main terminal bud may possess two or more subsidiary buds. Again, during actual growth a shoot may suddenly divide or even become fasciated, for no very obvious reason. Often in such cases as these there arise shoots bearing typically false-reverted foliage. It is probable that some unseen form of injury, such for instance as irritation resulting from mite attack, may explain them, but many shoots and young bushes showing the symptoms of false reversion have been kept under observation, and they have shown no sign of ultimately developing true reversion. Plate V., Fig. 2, shows a divided tip of this nature.

Thirty-two cuttings of Boskoop Giant and French Black having divided tips were selected in 1923 as cuttings. Since then all have produced normal bushes. Young bushes of Baldwin, Boskoop, Goliath, Seabrook's and French, selected from the nursery rows in 1923 as having divided tips, have similarly since remained healthy.

In connection with this damage to tips, it is interesting to recall that as far back as 1914 Mr. E. A. Bunyard (10) was warning growers not to injure the terminal growths of their black currants since this was liable to produce reversion. It would now appear probable that what he then referred to was in reality the false reversion here described.

(c) *The Forcing into Growth of Dormant Buds.* Towards the base of most Black Currant shoots and on the lowest portions of every bush, there exist buds that are unlikely, under normal conditions, to break into growth during the current season or perhaps for many seasons. Any unusual circumstance, such as extremely hard cutting back, which may force these dormant buds into growth, will produce a state of false reversion similar to that already described, although it often appears in a more extreme form.

In 1922 certain grafting experiments with black currants, which are described elsewhere (18), resulted in forcing many of the immature buds at the

bases of the stocks into growth, and these growths showed all the symptoms of false reversion.

Two series of experiments were carried out during 1924. The first was planned with a view to studying the nature and behaviour of the basal buds on one-year old wood already referred to. Twenty cuttings were prepared, consisting of two-year wood except for their tops which had been cut just above the junction of the two- and one-year old wood, so that the topmost buds of the cutting, i.e., those likely to be forced into growth in the first season, were the dormant buds at the base of the one-year old shoot. Any fully developed buds present were rubbed out so as to ensure the breaking of the normally dormant basal ones. In all cases, these cuttings when planted produced from the dormant buds shoots with foliage showing false reversion. In the following year the young bushes from these cuttings were quite normal. The upper portions of the one-year old wood removed in making these cuttings were used as " controls," and they produced normal foliage even in the first season.

In the second experiment, ten one-year old bushes of French were cut down to within an inch or so of the ground, and all fully developed buds which remained were rubbed off, only small dormant buds remaining. The same number of similar bushes were likewise cut down, but the fully developed buds were allowed to remain. The first lot of ten bushes produced some forty shoots, the leaves of all of which showed false reversion, though an occasional sucker arising from underground produced normal leaves only. All these bushes behaved normally in the subsequent seasons. The second lot of ten bushes (control) produced shoots with practically all normal foliage, though here and there the hard cutting forced a less well developed bud into growth with the result already described.

It is no uncommon practice for commercial growers to cut bushes back to ground level, usually for propagation purposes, and in such cases numerous false-reverted shoots are often apparent. Plate VI., Fig. 1, illustrates false reversion resulting from such hard cutting, whilst Fig. 2 shows the return to normal foliage in the following season.

(d) *Check due to Drought.* Following the check in growth which may occur during a spell of dry weather, growths appearing later in the season frequently show characteristic symptoms of false reversion. Except when this check occurs very early in the season, such cases can be readily diagnosed, when rogueing, from the features of the leaves immediately below the point at which the growth was checked.

VI. Alteration in General Leaf Shape.

So far, throughout the present account, the writers have concentrated attention upon those particular leaf characters, viz. the submain veins and teeth of the central lobe, which were originally emphasised by Lees. Since

amongst persons working on reversion these characters have become more or less an accepted standard for judging normality or otherwise in the black currant, they provide a common basis for recognition and discussion ; but this does not necessarily preclude the possibility, for diagnostic purposes, of additional standards being employed which may be almost equally constant, although not so easily capable of reduction to a quantitative basis.

In several of his papers, Lees himself refers to the abnormally narrow leaf (11) and the relative elongation of the leaf, characters considered useful by growers (7). He also discusses the size and colour of the leaves (7), but he did not consider these characters sufficiently constant or capable of reduction to rule as to be, in general, of primary diagnostic importance or value. Whilst this is in the main true, it would nevertheless seem to be of advantage to draw the attention of growers to certain other features of reverted leaves which provide additional help in formulating a fuller conception of the general characters of reversion.

In order to measure the actual differences in leaf shape and size, which seem so generally obvious, one hundred leaves were collected in the summer of 1921 from the middle portions of the current year's growth of both healthy and reverted bushes of four varieties, i.e. 800 leaves in all. It should be stated that the leaves were taken indiscriminately from the middle of the shoots, i.e. the June growth, so that from the reverted bushes a certain proportion of the leaves gathered actually appeared normal. Hence it must be realised, when the measurements given below in Table IV. are examined, that the figures do not express an extreme case such as would have resulted if only four-submain-veined leaves had been selected, but they rather give that general impression which would meet the grower's eye when beginning rogueing operations. In each case five different measurements were taken, all of which showed the general tendency of the reverted leaf to become relatively narrower and smaller and to " flatten out " at the base, owing to the reduction in depth of the basal sinus. The three sets of figures given below, illustrate these general tendencies, which, in fact, would

Table IV.

Average Measurements in mm. of Central Leaves from Healthy and Reverted Bushes.

Variety.	Breadth across basal lobes.		Length from Apex to Base.		Depth of basal sinus.	
	Normal.	Revert.	Normal.	Revert.	Normal.	Revert.
Boskoop Giant ..	71	56	81	71	13	8
Baldwin ..	64	51	76	66	10	8
Goliath	71	53	79	66	10	8
French	81	66	89	81	8	3

appear more emphatic with a collection consisting of nothing but reverted (i.e. four-submain-veined) leaves. Similar sets of measurements were made on 800 leaves taken from the bases and tops of the same shoots, but these did not show the same tendency.

Probably the most useful and constant character of these three determinations is the reduction in depth of the basal sinus or indentation at the base of the leaf. This is well shown in Plate I.

Again, another constant feature is the difference in texture of the leaf surface between normal and reverted leaves. Whilst the normal leaf is provided with a fine network of subsidiary veins and in consequence is relatively smooth surfaced, the reverted leaf is notably deficient in them, with the result that the surface of the latter is more coarsely rugose. This may also account in part for the deeper colour of the foliage on reverted shoots which has been noted by several observers, during the latter part of the growing season. Shortly after bud breaking, reverted bushes can readily be detected by the yellow-green foliage.

VII. General Habit of Growth: "Nettlehead."

From the earliest writings on reversion, "nettleheaded" growth was recognised as one of the very common symptoms (13). Many of the lateral buds, which normally produce fruiting trusses only, break into wood growth and produce this crowded appearance. (See Plate VII.). As far as the writers know, the causes of this type of growth have not yet fully been worked out, although Lees (12) has analysed it in considerable detail, in relation to the history of individual buds. However, it must be emphasised here that the terms nettleheadedness and reversion are by no means synonymous. For instance, if a reverted bush be cut back hard it produces straight shoots in the succeeding season with no sign of nettleheadedness. This process can be repeated year after year.

Again, nettleheaded growths are not infrequently produced on healthy bushes owing to some cause other than reversion, such for instance as accidental damage (See however 13). Such nettleheaded growths do not necessarily revert subsequently, and have quite normal leaves, unless the damage has occurred during the growing season.

In order to test this latter point, in March, 1922, just before some healthy bushes of French Black started into growth, twenty-eight tips were deliberately damaged. They produced typical nettleheaded growth, but in foliage appeared quite normal. Ten of them were kept under observation for three subsequent years. The bushes behaved perfectly normally, producing normal shoots and crops, and showing no signs of true reversion, although they were never pruned. This experiment was repeated in 1924 upon ten other plants (twenty-four shoots

PLATE VII.

Branch of Boskoop Giant showing typical reverted leaf characters and nettlehead growth.

Normal branch of Boskoop Giant. Close examination shows the difference even in shape of blossom.

in all). The results confirmed the previous observations. Great care must therefore be exercised in using type or habit of growth by itself as a diagnostic character of reversion.

VIII. Character of the Flowers.

In May, 1917, the writers described in the Gardeners' Chronicle (14) the abnormal blossom which they had found in extreme cases of reversion in black currants, and they then suggested that "where reversion leads to complete sterility some defect in the flower is to be looked for." Unknown to them Professor Ritzema Bos had described a similar condition in Black Currant flowers in Holland in December, 1904 (1). He even appears to connect this with sterility in the bushes, and a change of colour of foliage as well as flowers.

In May, 1921, the writers, in a paper on "The Running Off" of Black Currants" (15), pointed out that :—

> "from the time a branch can be definitely diagnosed as 'reverted' the blossom borne thereon begins to undergo a change. On bushes only partially reverted it is easy to see the two types of blossom side by side on consecutive branches. Like the general symptom of the leaves, the whole process appears to be one of lengthening out. The raceme itself tends to become long; so do the pedicels, the flower becomes more tubular than naturally urn-shaped, the sepals become more pointed and highly coloured, the petals become much narrower and as a result appear more distinct. The style begins to lengthen abnormally, bringing the receptive surface of the stigma well above the anthers. The whole colour of the flower truss in bud is notably different. The long dense hairs, giving an appearance of bloom on the normal buds, are replaced by a few very short ones so that the truss looks brighter in colour.
>
> "As the flowers unfold they appear almost transparent, lacking the normal pubescence, and the under side of the sepals appears remarkably highly coloured.
>
> "Between these first symptoms of 'reverted' blossom and those extreme cases described in 1917, we have found at different times and upon different bushes various stages of abnormality and abortive flowers."

It at once became obvious that if these highly coloured flowers were a constant and invariable characteristic of reversion, they might prove an extremely valuable and easy means of diagnosis. An additional aid would be the fact noted by Mr. H. Goude (17) and other observers that branches bearing abnormal flowers come into blossom before the normal ones. By marking and

observing a considerable number of branches as soon as they showed the symptom, it was proved at East Malling that these highly coloured flowers appeared only upon branches which concurrently or subsequently showed reverted leaves. On the other hand, not infrequently, branches which had been marked as showing the leaf symptoms of reversion did not show the highly coloured flowers.

The connection between the two (foliage and floral) manifestations of the disease was very carefully followed out in 1923, 1924 and 1925 on a number of bushes of five varieties. The following table gives the conclusions reached.

TABLE V.

Diagnosis of Reversion from Flower Characters.

Variety.	No. of Bushes Reverted. Diagnosed by foliage.	No. diagnosed by Blossom characters first.	No. which did not show highly coloured flowers.
Boskoop	19	9	10
Seabrook's ..	13	7	6
French	19	9	10
Goliath	9	3	6
Baldwin ..	1	0	1
Total ..	61	28	33

This method of diagnosis, then, was only successful in rather less than half of the cases. Moreover, in a rainy season, it would not have been possible to identify even this proportion, since, on the wet blossoms, the normal grey hairy pubescence is masked. Again, the distinction in blossom characters is far more readily seen in varieties such as Seabrook's, French and Boskoop Giant, where the flowers are normally darker coloured, than in varieties such as Goliath and Baldwin which have paler flowers. Finally, the actual period over which this operation can be performed is comparatively brief. Thus the claim put forward by Mr. W. P. Seabrook (16) that " this certain guide (to the identification of reversion) is to be found in the flowers," would appear, at any rate under many conditions, to require some qualification.

The rogueing of Black Currant plantations during the blossoming period may be a useful additional precaution, but by itself it is an insufficient measure of eradication, and if solely relied upon, it would preclude the taking of cuttings from young stools and bushes bearing no blossom, which, after all, are the best sources of cuttings provided they are properly rogued on the basis of leaf characters.

It was not found possible to correlate entirely the degree of reversion as manifested by the leaves with the presence or absence of highly coloured flowers. In eight of the cases already quoted, where flower characters did not show reversion, the leaf symptoms were definite but not extreme ; but in ten other cases in which the flower characters showed well, the leaf symptoms were very similar.

IX. THE NON-CROPPING OF REVERTED BUSHES.

Although there are persons who would have us believe that reverted bushes can be induced to continue to crop, it can confidently be stated that such cases are very exceptional, since growers would certainly not have bothered themselves over manifestations of abnormal growths, leaves, and blossom if the crop had remained a profitable one. That reversion ultimately leads to sterility in the vast majority of cases is indisputable. Most of the cases of heavy cropping on so-called reverted bushes can be attributed to one of two causes. Many bushes revert piecemeal, and, although one branch may be in an advanced stage of reversion, and consequently practically barren, the rest of the bush may be apparently normal and be cropping heavily. Numbers of such cases have been kept under close observation at East Malling and they show that the diminution of crop is only gradual, keeping pace with the progress of the disease. There are, on the other hand, other cases in which whole bushes develop extreme symptoms of reversion very suddenly. Frequently, on such bushes, heavy crops are borne in the same season as that in which the disease first becomes apparent, but in the following and succeeding years they produce practically no fruit. The general tendency in such bushes, however, is for a marked reduction of the crop to occur in the first season of reversion.

In 1921 a certain number of branches were marked on the same bush in a number of instances, some branches showing normal blossom and others highly coloured flowers, some showing normal and others reverted leaves. In all, some 400 individual flower trusses were kept under observation, and the fruits were ultimately counted and weighed. The nett result on the variety chosen, French, was that approximately double the number of fruits set per truss on the normal branches, and these fruits were more than double the weight of those produced on the reverted branches. Further, there was nearly double the number of trusses per 12 inches of normal wood as compared with an equal length of reverted wood. The observations were subsequently repeated on the varieties Baldwin and Blacksmith with similar results.

The disastrous nature of reversion to the grower is well illustrated by figures, obtained in 1924 and 1925, by selecting at random a few healthy bushes of Baldwin Black and a few extremely reverted bushes of the same variety,

growing under identical conditions. Accurate crop weights were taken of these with the following results.

		Reverted.	Healthy.
1924.	No. of bushes used	6	6
	Average crop in oz.	25·5	114
1925.	No. of bushes used	3	6
	Average crop in oz.	2	45·5

Nevertheless, although sterility is almost invariably associated with reversion, it is not a safe or sufficient symptom by itself on which to base a system of rogueing.

In the paper already referred to (15), the writers have taken pains to distinguish between the true "running off" of the fruit, so common on healthy bushes of certain varieties, due to lack of fertilisation, and the so-called running off on reverted bushes, which must be associated intimately with that trouble. Although the writers have tried on many occasions to obtain a normal set of fruit upon reverted bushes by hand pollinating each individual flower, they have invariably failed to do what has readily been accomplished by the same means on healthy bushes.

Summing up, therefore, whilst such symptoms as sterility, densely branched growth (nettleheadedness) and highly coloured flowers may all be of a certain amount of assistance to the grower in his rogueing operations, for practical purposes they must all be considered of secondary importance in comparison with leaf characters, both because the symptoms mentioned are neither universally attributable to reversion nor an essential accompaniment of it, and because they are not applicable when working with the best source of cuttings, viz. the young unfruited bush.

If, on the other hand, the distinction between true and false reversion is once mastered—and the causes of the latter are, in fact, quite patent—the rogueing by leaf character, concentrating upon the submain veins and teeth of the central lobe, is by no means a difficult or uncertain process. To what extent it has been used satisfactorily at East Malling will be detailed in a later paper.

SUMMARY.

1. The leaf characters of Normal and Reverted bushes are discussed in detail, in relation to varietal differences, to the position of leaves on the shoot, and to different types of leaf.
2. The veining and serration of leaves are recommended as the only sure diagnostic characters for "rogueing."
3. The causes of "false" reversion and methods of distinguishing it from true reversion are described.

4. Other less constant characteristics of reverted bushes, such as nettleheadedness, character of flowers, and non-cropping are described as additional aids in diagnosis of the disease.
5. Series of experiments on various aspects of this work are described in detail, and the figures and measurements are presented.

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FIELD EXPERIMENT ON THE MANURING OF GOOSEBERRY BUSHES.

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As a part of the general scheme of investigations proposed by this Station on the nutrition of fruit trees, a manurial experiment on gooseberry bushes was commenced during the spring of 1921.

At that time there was no land available on the station farm which was considered entirely suitable for this purpose but as it appeared that no such area would become available for at least four or five years it was decided to lay down a series of plots on land vacant at that time. It was thought that the experiment would furnish data on major points and would be of value in developing a technique for more refined experiments in the future.

A plot of land, approximately one acre in area, was selected accordingly for the purpose.

The experiment has been continued until the present time and certain results have been obtained which it appears desirable to place on record at this stage although it is proposed to continue the experiment for a further period.

Experimental.

Site and Soil.

The surface of the plot is not level but slopes away gently from the north-west corner towards the east and south-east.

The soil over the whole plot is a sandy loam derived from the Keuper Marl formation. Mechanical analyses were carried out on samples of surface soil taken from various parts of the plot prior to planting and these showed that the texture of the soil varies across the plot in the direction of the slope, being heaviest on the west side of the area and lightest in the region of the east and south-east sections of the plot. The results of the analyses of the samples from the extreme west and east sides are given in Table I., in which table certain chemical data are also presented.

The Plots.

The area was planted in February, 1921, with one-year-old gooseberry bushes of the variety Keepsake, the bushes being planted at six feet square, the rows running north to south and east to west. The main block was sub-divided into sixteen plots for differential manurial treatments.

TABLE I.

Soil Analyses. Samples taken October 1920.

Analyses on air-dried samples.

	West Side. Surface Soil. %	East Side. Surface Soil. %
Mechanical Analysis :		
Stones in sample	Nil.	Nil.
Fine Gravel	0.34	0.36
Coarse Sand	10.42	13.09
Fine Sand	36.28	43.36
Silt	10.87	11.77
Fine Silt	19.16	14.29
Clay	11.14	5.11
Chemical Analysis ;		
Moisture	3.61	2.60
Loss on Ignition	7.44	7.97
Potash—Total (K_2O)	0.839	0.520
„ "Available" (K_2O)	0.0092	0.0064
Phosphoric Acid—Total (P_2O_5)	0.112	0.099
„ "Available" (P_2O_5)	0.0127	0.0142
Carbonate of Lime	Nil.	Nil.
Lime Requirement	0.202	0.282

The plots were laid out in strip fashion, each consisting of two rows of bushes, running north and south and each row containing twenty bushes. Each plot was separated from the adjoining plots by means of single buffer rows of bushes.

MANURIAL TREATMENTS.

The field in which the plots are located was a meadow previous to 1917 and had probably been utilised for that purpose for many years. During that year the turf was ploughed out and from then until 1921 a straw crop was taken from the field each season. During the arable period the only manures applied were a dressing of basic slag at 5 cwts. per acre and a dressing of low grade shoddy at one ton per acre.

A dressing of lump lime at the rate of one ton per acre was applied during the winter of 1920-21.

The scheme of differential manurial treatments proposed for the gooseberry plots is shown in Table II.

The proposed ingredients of the "organic" manure were dried blood, steamed bone flour and sulphate of potash and of the "inorganic" manure, sulphate of ammonia, superphosphate and sulphate of potash.

In all cases excepting Plots 2, 10, the weights of manures applied were calculated to supply nitrogen at 50 lbs. per acre ; "total phosphates" at 120 lbs. per acre ; potash (K_2O) at 50 lbs. per acre.

TABLE II.

Manurial Treatments.

Plot Nos.	Manurial Treatments.
1, 9	No manure.
2, 10	Dung at 10 tons per acre, each Spring.
3, 11	Complete " organic " manure (non-bulky), each Spring—to supply Nitrogen, Phosphates, Potash.
4, 12	Complete " inorganic " manure, each Spring—to supply Nitrogen, Phosphates, Potash.
5, 13	Complete Manure : Mixture of " organic " and " inorganic " materials in equal parts, each Spring.
6, 14	As 5, 13, less Nitrogen, each Spring.
7, 15	As 5, 13, less Phosphates, each Spring.
8, 16	As 5, 13, less Potash, each Spring.

Diversions from this scheme have been as follows :

1924, 1925—Muriate of potash was used vice sulphate of potash.

1924 onwards—On plots receiving potash, the rate was at 100 lbs. (K_2O) per acre.

1925, 1926—Nitrate of soda was used vice sulphate of ammonia.

The dung has been spread evenly over the whole areas of the " dung " plots but not ploughed in and the various mixtures of " artificials " have been broadcasted evenly over the areas of plots to which they were to be applied.

MANAGEMENT.

The plots have been subjected to the ordinary commercial methods of management. Cultivations have been carried out both by horse and hand labour ; control and preventive measures have been taken against insect pests and fungus diseases. Special arrangements were made for carrying out all operations involving records.

GROWTH FEATURES.

During the course of the experiment an attempt has been made to distinguish points of difference in the growth features of bushes undergoing the various treatments. Experience with fruit trees under different nutrient treatments in sand cultures has shown that deficiencies of nitrogen, phosphorus and potassium respectively produce certain specific effects on the growth characters of the plants (1) and hence in the present experiment careful observations have been made with a view to determining whether the various treatments could be associated with particular features exhibited by the plants.

The special points to which close attention was given were times of bud break, types and amounts of shoot growth, foliage characters, times of defoliation and tints developed during defoliation.

So far no differences have been observed in the times of bud break. In pot experiments, time of bud break has usually been appreciably delayed only in cases of acute starvation from nitrogen or phosphorus and as it will be shown later that the treatments " nitrogen omitted " and " phosphates omitted " have not produced substantial starvation effects to date it is not to be expected that any marked effects on bud break would have been exhibited.

It has been stated previously that the texture of the soil of the plots shows considerable variation in the general direction of west to east—i.e., across the plots from Plot No. 1 to Plot No. 16—being heaviest in the north-west corner of the plots and lightest in the south-east area. During the first season it soon became apparent that the differences in soil texture were reflected in the growth of the bushes. The season was remarkable for an early summer drought and the weather conditions prevailing were very unfavourable to the establishment of the newly planted bushes. Those on the plots located on the heavier soil on the west half of the area—Plots Nos. 1 to 8—made much better growth than those situated on the east side—Plots Nos. 9 to 16—and growth was especially poor on the southern portion of the latter plots. Throughout the season the majority of the bushes showed severe leaf scorch.

The initial superiority of the bushes on Plots Nos. 1 to 8 over those on Plots Nos. 9 to 16 has been maintained throughout the course of the experiment and in view of these observations it has been necessary to treat the quantitative data secured in a special manner. The variation has added a point of great interest to the experiment as it will be shown later that the heavier and lighter areas of the plots present distinct manurial problems.

The most noticeable feature of growth has been the exceedingly poor growth made by the bushes on Plots Nos. 8, 9 and 16, the sizes of these bushes contrasting strongly with those of bushes on the other plots. The failure of the bushes in these cases appears to be due to an insufficent supply of potash in these lighter areas, as the failures have been associated with very severe leaf scorch and where potash has been supplied to similar soil areas in Plots Nos. 11 to 15, growth has been good and leaf scorch, which was severe in the early stages of the experiment has been in the later stages relatively slight. (See Table IV.)

It was not possible to take measurements of shoot growth but prunings taken from the bushes during the course of the normal winter pruning operations have been weighed. The data secured during the last two winters are given in Table III.

There are several points of interest revealed in the data which are clearly shown in the last three columns of the Table.

TABLE III.

Prunings.

Series.	Plot No.	Winter 1924-25. Weights of prunings. Kilos.	Winter 1924-25. No. of bushes.	Winter 1924-25. Average weights prunings per bush. Kilos.	Winter 1924-25. Order of weights.	Winter 1925-26. Weights of prunings. Kilos.	Winter 1925-26. No. of bushes.	Winter 1925-26. Average weights prunings per bush. Kilos.	Winter 1925-26. Order of weights.	Two Seasons. Totals of average bush. Kilos.	Two Seasons. Order of weights.	Two Seasons. Percentage of Unmanured.
A.	1	5.19	40	0.130	4	11.14	39	0.286	5	0.416	5	100
	2	9.02	40	0.226	1	17.44	40	0.436	2	0.662	1	159
	3	5.46	40	0.137	3	17.10	39	0.438	1	0.575	2	138
	4	7.33	40	0.183	2	14.62	38	0.385	4	0.568	3	137
	5	5.07	39	0.130	4	15.30	39	0.392	3	0.522	4	125
	6	4.18	38	0.110	6	10.00	37	0.270	6	0.380	6	91
	7	3.98	40	0.100	7	9.90	38	0.263	7	0.363	7	87
	8	2.29	40	0.057	8	3.60	40	0.090	8	0.147	8	35
B.	9	3.04	40	0.076	7	4.16	39	0.107	7	0.183	7	100
	10	5.23	40	0.131	1	11.36	38	0.300	1	0.431	1	236
	11	3.05	39	0.078	6	7.87	37	0.213	4	0.291	4	159
	12	3.96	39	0.102	3	10.46	39	0.268	2	0.370	2	202
	13	4.18	39	0.107	2	9.11	37	0.246	3	0.353	3	193
	14	3.25	38	0.086	5	6.53	34	0.192	5	0.278	5	152
	15	3.78	40	0.095	4	6.64	38	0.175	6	0.270	6	148
	16	1.02	37	0.028	8	1.91	35	0.054	8	0.080	8	44

In the first place it will be seen that it is indicated that the growth in Series A.—Plots Nos. 1 to 8—is generally larger than in the duplicate plots in Series B.—Plots Nos. 9 to 16.

Secondly, the low figures for Plots Nos. 8, 9, and 16 contrast strongly with those for the remainder of the plots.

In Series A. the highest values are obtained for the plots receiving dung and "complete manure" and the "no manure" plot is fifth.

This latter plot is also higher than all plots in Series B. with the exception of Plot No. 10 which receives dung.

In Series B. the dung plot shows the highest value, "complete manure" plots come next, followed by "nitrogen omitted," "phosphorus omitted" and then "no manure" and "potash omitted" much below. This order probably represents a fairly true picture of the effects of the manurial treatments over this series, though perhaps the actual weight values for Plots Nos. 14, 15, and 16 are all somewhat lowered by poorer soil conditions. In connection with the effects of the treatment on Plot No. 16—"potash omitted"—it is interesting to note that on Plot No. 8—receiving the same treatment—the value obtained is only 80 per cent. of that on Plot No. 9, which adjoins it and on which soil conditions appear comparable.

The foliage characters on the plots have been normal with the exception that bushes on all plots have exhibited symptoms of leaf scorch. During the

TABLE IV.

Leaf Scorch.

Series	Plot Nos.	27/6/24	23/6/25	26/8/25		21/6/26
		Nos. of affected bushes.	Nos. of affected bushes.	Total Nos. affected bushes.	Nos. seriously affected.	Nos. of affected bushes.
A.	1	0	0	36	10	0
	2	3	1	17	2	0
	3	4	1	16	0	0
	4	1	1	12	0	0
	5	3	0	8	0	0
	6	0	2	15	0	0
	7	2	4	19	1	0
	8	28	28	38	32	31
B.	9	26	24	34	30	25
	10	10	6	23	11	2
	11	7	7	22	9	1
	12	11	5	15	3	2
	13	4	5	18	5	4
	14	8	4	19	5	2
	15	3	5	24	0	1
	16	35	27	35*	26	26

* Also Total No. bushes on Plot.

first two years of the experiment scorching was extremely prevalent excepting on the north-west corner of the area where the soil is heavier. At this stage the bushes in the south-east corner were the most severely affected.

As the experiment has progressed the trouble has been greatly reduced excepting on Plots Nos. 8, 9 and 16, where it has continued to be very severe and has shown no signs of improvement.

Detailed observations have been made on the condition of the individual bushes on various dates during each season and representative data from the records made are presented in Table IV.

Two points stand out very clearly in the Table. The more striking of these is that leaf scorch has been most severe on Plots Nos. 8, 9 and 16 and the other is that it has been more prevalent on the plots in Series B. than in Series A.

It is also noticeable that scorch has only been widespread on Plot I. on one occasion and that at this time the trouble was more prevalent than usual on all plots.

The chief points relating to defoliation which have been noted are as follows:

Defoliation has occurred on Plots Nos. 8, 9, and 16 in advance of that on the other plots.

On Plots Nos. 2 and 10 the bushes have retained their leaves slightly longer than on any other plots.

During the period of defoliation the bushes on all plots have exhibited leaf scorch symptoms rather than yellowing or purpling of the foliage.

Diseases.

Each season the bushes have been affected with American Gooseberry Mildew and it has been necessary to spray and "tip" the bushes as control measures.

The season of 1924 was an extremely wet one and following on this period a severe attack of botrytis occurred. Data obtained on the incidence and severity of the disease are presented in Table V.

The data show that the disease was distributed over the whole of the plots and that relatively small amounts of damage resulted on plots Nos. 8, 9 and 16.

Crop.

Crops records for the seasons 1922 to 1926 inclusive are available for comparison and are presented in Tables VI. and VII.

In 1922, the first year of bearing, the crop was very small and in view of this, total weights per plot only were obtained. In all subsequent seasons crop weights and numbers of berries per bush have been obtained.

Early in the experiment it was noticed that soil variation was exercising a large effect on growth on the southerly halves of certain of the plots between

TABLE V.

Botrytis Infections—Showing numbers of affected bushes and weights of dead wood removed.

Series	Plot Nos.	March, 1925.			March, 1926.		
		Nos. of bushes affected.	Prunings gms.	Nos. of bushes killed.	Nos. of bushes affected.	Prunings gms.	Nos. of bushes killed.
A.	1	14	960	1	6	217	1
	2	14	820	0	3	334	0
	3	16	890	1	6	333	0
	4	11	1160	2	10	1584	3
	5	4	400	0	10	1215	2
	6	8	1110	1	7	925	2
	7	4	430	1	5	427	1
	8	?	30	0	9	96	0
B.	9	8	260	1	9	121	0
	10	6	251	2	11	539	1
	11	6	310	1	4	458	1
	12	7	160	0	11	597	1
	13	8	290	2	7	782	1
	14	8	810	3	8	267	1
	15	6	320	1	6	190	2
	16	2	50	0	2	12	0

Plots Nos. 9 to 16 and hence it was decided to include only the twenty-two bushes at the northerly end of each of these plots for consideration in the cropping records.

In addition to this certain large effects due to botrytis ravages were apparent on bushes during 1925 and 1926 and these have been excluded from the data presented.

In view of these circumstances the data are given on an " average bush " basis in Table VII. to allow of comparisons being made.

Examination of the results shown in Table VII. reveal the following points :

In Series A. there is a falling off in crops in passing from Plot No. 1 to Plot No. 8. The highest crops were obtained on Plot No. 1—the unmanured plot. The yields on Plot No. 8 were very much below those on any other plot being only 51 per cent. of those on Plot No. 1.

In Series B. the highest crops were obtained on the plots receiving dung and " complete manure " and the unmanured plot was only sixth in order of cropping. The crops on Plots Nos. 14 and 15 were considerably lower than those on the " complete manure " plots. On Plot No. 16 the crops obtained were only 21 per cent. of those obtained on Plot No. 9. Plots Nos. 16 and 8 gave the lowest yields, the crops on the twenty-two bushes at the north end of the latter plot being only 90 per cent. of those of the corresponding bushes on the adjoining unmanured plot.

TABLE VI.

Cropping Data.

Plot Nos.	Season 1922.		Season 1923.		Season 1924.		Season 1925.		Season 1926.	
	No. of bushes.	Total crops. Kilos.	No. of bushes.	Total crops. Kilos.	No. of bushes.	Total crops. Kilos.	No. of bushes.	Total crops. Kilos.	No. of bushes.	Total crops. Kilos.
1	40	2.36	40	13.63	40	47.71	35	62.20	35	61.00
9	40	1.04	22	7.95	22	19.20	21	24.24	21	23.04
2	40	1.34	40	14.54	40	41.40	33	70.23	33	50.63
10	40	1.12	22	9.23	22	21.21	20	42.30	20	27.54
3	40	2.28	40	14.83	40	40.40	35	74.53	35	45.45
11	40	1.12	21	7.74	21	21.18	16	35.29	16	27.08
4	40	1.94	40	19.65	40	41.37	33	67.12	33	42.98
12	40	1.12	22	10.87	22	23.01	21	42.68	21	32.07
5	40	1.22	39	13.64	39	34.62	33	69.99	32	39.25
13	40	1.64	22	10.90	21	21.62	19	26.21	19	32.29
6	40	1.56	39	13.68	39	35.65	29	57.64	28	35.01
14	40	1.18	22	9.00	21	18.83	16	17.74	16	22.05
7	40	1.34	40	12.29	40	39.83	34	63.61	34	40.83
15	40	1.08	22	7.12	22	17.05	19	13.57	19	24.99
8	40	1.24	40	10.95	40	25.08	38	33.14	38	29.30
16	40	0.82	22	2.05	21	4.98	21	1.10	19	6.46

TABLE VII.

Cropping Data.

Series.	Plot Nos.	Season 1922. Average per bush. Kilos.	Season 1922. Order of cropping.	Season 1923. Average per bush. Kilos.	Season 1923. Order of cropping.	Season 1924. Average per bush. Kilos.	Season 1924. Order of cropping.	Season 1925. Average per bush. Kilos.	Season 1925. Order of cropping.	Season 1926. Average per bush. Kilos.	Season 1926. Order of cropping.	Period 1922–26. Totals of average bush. Kilos.	Period 1922–26. Order of cropping.	Period 1922–26. % of unmanured.
A.	1	0.0590	1	0.3408	6	1.1928	1	1.7771	7	1.7429	1	5.1126	1	100
	2	0.0335	5	0.3635	3	1.0350	2	2.1282	2	1.5342	2	5.0944	2	100
	3	0.0570	2	0.3708	2	1.0100	4	2.1294	1	1.2986	4	4.8658	4	95
	4	0.0485	3	0.4913	1	1.0343	3	2.0339	4	1.3024	3	4.9104	3	97
	5	0.0305	8	0.7497	5	0.8873	7	2.1209	3	1.2266	6	4.6154	5	90
	6	0.0390	4	0.3508	4	0.9141	6	1.9876	5	1.2503	5	4.5418	6	90
	7	0.0335	5	0.3073	7	0.9958	5	1.8709	6	1.2009	7	4.4084	7	86
	8	0.0310	7	0.2738	8	0.6270	8	0.8721	8	0.7711	8	2.5749	8	51
B.	9	0.0260	7	0.3614	6	0.8727	6	1.1543	5	1.0971	7	3.5115	6	100
	10	0.0280	3	0.4195	3	0.9641	4	2.1150	2	1.3770	5	4.9036	3	140
	11	0.0280	3	0.3686	5	1.0086	3	2.2056	1	1.6925	2	5.3033	1	151
	12	0.0280	3	0.4941	2	1.0460	1	2.0324	3	1.5271	3	5.1276	2	146
	13	0.0410	1	0.4955	1	1.0295	2	1.3795	4	1.6995	1	4.6450	4	132
	14	0.0295	2	0.4091	4	0.8967	5	1.1088	6	1.5031	4	3.9472	5	113
	15	0.0270	6	0.3236	7	0.7750	7	0.7142	7	1.3153	6	3.1551	7	90
	16	0.0210	8	0.0932	8	0.2371	8	0.0524	8	0.3400	8	0.7437	8	21

DISCUSSION.

In considering the significance of the various data which have been obtained it is very essential to bear in mind the nature of the soil variation which occurs over the area.

The data presented for prunings, leaf scorch and cropping show that the variations influenced appreciably the performance of the bushes. It is evident that the conditions became less favourable for the growth of the bushes in the direction of Plot No. 1 to Plot No. 16.

In considering the question of growth it will be useful to discuss both the qualitative observations made and the quantitative data obtained.

Throughout the experiment it was observed that growth was very poor on Plots Nos. 8, 9 and 16 and that bad growth was invariably accompanied by leaf scorch.

In the earlier stages of the experiment growth was much stronger on the heavier area than on the lighter and while leaf scorch was only slight in the former case it was very severe in the latter.

It thus appeared that the primary nutritional problem of the area was one which was characterised by leaf scorch.

The data given in Table III. indicate that there is a factor, other than manurial treatment, operating over the plots which tends to produce a descending gradient in growth from Plots Nos. 1 to 16—c.v. Plots Nos. 1, 9 ; 2, 10 ; etc.

Similarly, if the data for leaf scorch, given in Table IV., be examined it is seen that scorch is more prevalent on Plots Nos. 9—16 than on Plots Nos. 1—8.

Certain results appear to have been produced by the action of the manures and the magnitudes of these differ in the two series. Thus the results obtained from "dung" and "complete manure" treatments in both series indicate substantial increases in growth from these treatments—in Series A. the percentage increases are from 59 per cent. to 25 per cent. and in Series B. from 136 per cent. to 59 per cent.

Although the figures obtained for "nitrogen omitted" and "phosphorus omitted" in Series A. show a decrease when compared with Plot No. 1, there is no doubt that the decrease is not due to the action of the manurial treatments but is to be attributed to soil variation since the figures for these plots show large increases over that for Plot No. 9 where the soil conditions are more comparable. In Series B. the figures for these treatments are approximately 50 per cent. above that for Plot No. 9.

The results obtained on Plots Nos. 8 and 16 are of great interest. They show very clearly that from the manurial viewpoint potash is the limiting factor to growth on the lighter area of the plot. They also demonstrate a second point which may have an important practical bearing. This point is that the manurial treatment given to Plots Nos. 8 and 16, where potash is the limiting

factor, viz. :—application of nitrogen and phosphates without addition of potash—appears to have been detrimental to the growth of the bushes. Thus the prunings taken from Plot No. 8 have only been 80 per cent. by weight of those removed from the adjoining Plot No. 9. The results for crop weights are in the same direction.

In the writer's opinion such an effect could be produced by the manurial treatments given to Plots Nos. 8 and 16 by the action of the manures in promoting the development of leaf scorch which results in the early collapse of the foliage during the growing season.

The effect may be mainly due to the nitrogen contained in the manure (2) but there is evidence that phosphorus may also function in a similar manner.

The experiment has provided valuable information on the problem of leaf scorch. It has been frequently observed in cases of leaf scorch in commercial plantations that the trouble occurs in patches, on certain areas trees and bushes remaining free from it. In the present case scorch occurred on the lighter area of the plot and it is possible to see from the mechanical analyses data in Table I. the range of variation obtaining between the heaviest non-scorching area and the lightest area on which scorch was most severe. In addition to the differences in texture it will also be noted that the amounts of "total" and "available" potash differ markedly.

It is obvious from the data presented in Table IV. that in this experiment the potash manures applied have exerted a substantial controlling effect over leaf scorch. During the early part of the experiment practically the whole of the bushes on Plots Nos. 9 to 16 were severely affected with scorch whilst many on Plots Nos. 1 to 8 were also affected to varying degrees. Serious cases are now almost wholly confined to Plots Nos. 8, 9 and 16.

The data presented for August 26th, 1925 are interesting. Presumably climatic conditions previous to that date had been conducive to leaf scorch development. On this occasion there was a fairly serious outbreak on Plot No. 1 which appears to indicate that the bushes on that plot are not very far removed from the leaf scorch condition.

There is one point of interest attaching to the data accumulated on botrytis infections. It has often been found that potash manures exercise beneficial effects in cases of various fungus and bacterial diseases—e.g., on Stripe in Tomatoes caused by Bacillus *lathyri*. In the present experiment although practically every bush in Plots Nos. 8, 9 and 16 was exhibiting symptoms of acute potash starvation, the evidence obtained on botrytis distribution and effects indicates that potash exercised no beneficial effects in checking the outbreak. The most severe outbreaks occurred where bushes were making rapid growth.

In the cropping data there is further evidence of the effects of soil variation on the behaviour of the bushes—c.v. Plots Nos. 1, 9; 8, 16.

In Series A. the largest crops were obtained on Plot No. 1 receiving no manure, and there is a gradual falling off in cropping from Plot No. 2 to Plot No. 7. On Plot No. 8 the total crops were only 51 per cent. of those obtained on Plot No. 1.

In Series B. it should be noted that the treatments " dung " and " complete manure " gave substantially higher crops than those on the unmanured Plot No. 9. These increases can undoubtedly be attributed to the manures.

The yields on Plots Nos. 14 and 15 are of the same order as those on Plot No. 9, although the pruning data indicate that the bushes on these plots are much larger than those on Plot No. 9. It will be of interest to see whether this condition will be maintained in the future.

It was pointed out in discussing the growth data that the omission of potash from the " complete " manure appears to have exercised a detrimental effect on cropping. The yield on Plot No. 16 is extremely low whilst on Plot No. 8 the yield on the twenty-two bushes at the north end of the plot is only 90 per cent. of that on the corresponding bushes on the adjoining Plot No. 9.

It is of interest to compare the effects of the manures on growth and cropping. Such a comparison is possible in Series A. and appears to indicate that growth increase is not necessarily accompanied by a parallel increase in cropping.

Conclusions.

From the data presented in this paper the following deductions seem justified.

1. Considerable differences found in growth and cropping of the bushes are attributable to soil variation. The soil on the heavier areas is more suited to the growing of the bushes than is that on the lighter areas.

2. Substantial increases in growth and cropping have resulted from " dung," " complete organic " manure and " complete inorganic " manure on the lighter soil area. These manures have also increased growth on the heavier area. It is probable that increases have also resulted from nitrogen plus potash and " phosphates " plus potash.

The increases in wood growth due to manures were relatively greater than were increases in cropping.

3. Detrimental effects on growth and cropping apparently resulted from manuring with " nitrogen plus phosphates only " on plots where bushes were exhibiting symptoms of potash starvation.

4. Potash is the limiting factor to the growth of gooseberry bushes on the area.

5. Potash manures did not exercise any controlling action on botrytis spread. Strongly growing bushes were affected most and weakly bushes showing potash starvation were only slightly damaged.

SUMMARY.

1. A field experiment on "The Manuring of Gooseberries" carried out over six seasons is described.

2. Data are presented relating to growth characters, leaf scorch, botrytis infection and cropping.

3. The results show that certain effects are attributable to soil variation and others to the action of the manures—dung and "complete" manures.

4. Potash was found to be the limiting factor to the growth of gooseberry bushes over the area and the application of potash manures produced significant effects in increasing growth and cropping and in controlling leaf scorch.

5. The application of manures containing nitrogen and phosphates but no potash apparently affected the growth and cropping of bushes adversely.

6. Potash manures did not exercise any controlling action against botrytis infection.

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THE TIME OF DIFFERENTIATION AND THE SUBSEQUENT DEVELOPMENT OF THE BLOSSOM BUD OF THE PLUM.

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A knowledge of the history of a blossom bud prior to its expansion is not only of academic interest but is of value to the practical horticulturist. If it is known when the primordia of the flowers are laid down he may be able to intervene at the right time in order to influence the blossom bud production by pruning or manuring; or again, he should know whether the time of differentiation of the flowers can be varied by cultural treatments such as cover cropping and clean cultivation, stock influence, etc., and, if so, whether it is of value to him to retard or hasten the time of differentiation. In addition, it is a piece of knowledge necessary for the investigation of the problem of the causes of fruit bud formation.

I.—BRIEF HISTORICAL SURVEY.

As an introduction to the subject it was thought that a brief review of the work carried out at the time of blossom bud differentiation in America and elsewhere would be of value.

It is not possible to say when horticulturists first recognised the fact that fruit trees form their blossom buds in the year previous to their expansion. In 1812, Thomas Andrew Knight (3) wrote: "It has long been known to naturalists that the blossom buds of trees are generally formed in the season preceding that in which they unfold and execute their office." In 1656, Dr. Beale (1) wrote: "Before December . . . by the bluntness of the bud you may discover what branch will bear fruit the next summer immediately following . . ." Thomas Hitt (2) in his book, "A Treatise of Fruit Trees" (1757) in discussing the question of pruning fruit trees at the time of planting writes: "This shoot cutting or stumping is the most injurious to trees whose heads are furnished with branches of two or three years old, etc., whether apples, pears, plums, or cherries, for their buds are either prepared for blossoming the next spring . . ."—whence it may be concluded that he had observed that blossom buds developed in the year previous to their expansion. More recently scientific workers (especially in America) have gained a more exact knowledge of the development of the blossom buds of our cultivated fruits. In the tree fruits the date of differentiation has been determined and the development of the

buds has been traced right through to the expansion of the blossom. Such complete information with regard to the small fruits has not been obtained, but some work has been done on this subject as will be seen below.

The order of development of the flower parts has been shown to be quite regular. E. S. Goff (4), one of the earliest scientific workers on the subject, states that the order of development is the same in the different fruits, viz., first the calyx appears, then the petals, stamens and finally the pistil. All these parts are present before the winter sets in, the ovules and pollen grains not being formed until February or March of the following year. There are exceptions to this since Goff found that in the gooseberry ovules were generally present before the winter set in, and Drinkard (5), working with the Whitaker plum (*Prunus Munsoniana*) sometimes found that the ovules and pollen grains were present in December, but he regarded these buds as being exceptionally forward in development. During the period from November until the end of January or the middle of February the fruit bud is quiescent, or at least only cytological changes take place (Drinkard). At the end of the rest period a rapid elongation of the pistil takes place and the ovules are soon noticeable in the ovarian cavity. In the anthers the nuclei of the pollen mother-cells become enlarged and soon divide. Finally, the various walls of the pollen sacs become differentiated, the pollen grains become surrounded with a thick hyaline wall, and the anthers are ready for dehiscence.

Having outlined the general course of events, it will now be of advantage to give the details for the several kinds of fruit.

The Apple.

The development of the blossom bud of the apple has been traced by Goff (4), Drinkard (5), Kraus (6), Bradford (7), and Tufts and Morrow (8) in America and by Bijhouer (9) in Holland. Bradford, Drinkard and Goff working at Oregon, Virginia and Wisconsin, respectively, found that the earliest signs of differentiation could be seen at the end of June or in the first few days of July. Tufts and Morrow give June 11th as the earliest date at which flower buds could be distinguished. As regards the further development, Drinkard, working with the variety Oldenburg, found that the calyx and signs of stamen formation could be observed on July 14th. On August 26th the pistil had begun to develop and by the end of September the cavity of the ovary was distinct. During November and December only cytological changes took place and early in March the ovules commenced their development. Kraus in his paper on "The Gross Morphology of the Apple" (6) gives a detailed description of the origin of the flowers and of the flower parts. He found that "the first observable indication of the flower is the more or less thickening of the axis. Minute bracts, in the axils of which are formed blunt protuberances, arise from it in a very close spiral.

The tip of the axis never loses its identity, but on the contrary enlarges considerably and always develops slightly in advance of the protuberances immediately below it. Later, these protuberances develop into definite individual flowers." The order of the development of the flower parts has been described above and will not be gone into in more detail here. Kraus found that the ovules did not commence their development until growth was resumed in the spring and that the pollen grains were also not formed before the winter set in, but that the microsporagia passed the winter or rest period in the mother-cell stage. Bijhouer (9), working in Holland with the variety Calville St. Sauveur, describes as a preliminary stage to blossom bud formation, a broadening and flattening of the growing point. This took place in the first half of June. From mid-June to mid-July the sepal primordia of the terminal flowers of the truss were laid done. The petals were formed in the first half of August and later in that month the three whorls of stamens could be seen. By the end of August the carpel primordia were visible. During September the carpels grow and the anthers of the stamens became bi-lobed. Goff found that the period of fruit bud differentiation extended over some considerable time. This has been confirmed, and the time of differentiation has been found to vary with the position of the bud on the tree. This subject will be discussed later.

The Pear.

Drinkard gives mid-July as the time of commencement of differentiation for the variety Kieffer. Goff found that the earliest indications of flower formation could be seen on July 21st. Tufts and Morrow found that June 21st was the date for the Bartlett pear. Luyten and de Vries in Holland (10) saw the first signs of differentiation in August.

The Cherry.

Drinkard gives the first week in July and Goff about July 11th, as the time of the commencement of the differentiation. Tufts and Morrow also found the first signs of differentiation early in July.

The Plum.

Goff, working with a variety of *Prunus americana* gives July 8th as the date of the commencement of differentiation. It was shown by Drinkard that the early development of the fruit buds is not the same in all species of Prunus which he examined. In *P. hortulana* the flower parts did not commence differentiation until September, whereas those of *P. americana* and of *P. triflora* had commenced differentiation of their sepals by the end of July. However, all species had reached the same stage of differentiation by November, when the buds entered the resting stage. Luyten (11), working in Holland with the variety Drap

d'or D'Esperen (*P. domestica*) found that the primordia of the flowers were visible by July 23rd, and that the calyx could be discerned on August 7th, the petal primordia were visible by August 13th, and the stamens and the carpel by the end of the month. The loculus or cavity of the pistil could be seen on September 20th. She found no increase in the length of the fruit bud from October until mid-January.

The Small Fruits.

Very little work has been done on tracing the development of the flowers of the small fruits. Goff gives the beginning of August as the time of the commencement of formation of the flower parts of the Black Currant and mid-September for those of the Strawberry. MacDaniels (12) found that differentiation in the Red Currant and Gooseberry was commencing by mid-August, and that the Red Raspberry had undergone partial differentiation early in January. Ruef and Rickey (13) examined the differentiation of flowers in Strawberry runners, and found that the time varied with the position of the runner on the stolon, the flowers on the runners nearer the parent plant developing before those on runners further away. In the same way the primary flowers of the inflorescence developed before the secondary or tertiary ones. Thus differentiation was spread over a period, the first signs of flower formation being visible in early September, the rudiments of the latest formed flowers not being formed until December.

Variation in Time of Differentiation.

As has been stated above, the time of differentiation of the flowers of all kinds of plum is not the same; but more than one species was in question. It is the place here to consider the variation in time of differentiation within a species, i.e., among a number of different varieties, and also what is known of the variation caused by season, by the position of the bud on the trees, and lastly by the cultural treatments.

Variation Among Varieties.

Bradford examined nine different varieties of the apple and came to the conclusion that there was some little difference between varieties in their respective times of fruit bud formation and that there was more agreement between the time of differentiation and the time of blossoming, rather than with the time of ripening of the fruit,—in other words, a variety which blossoms early would commence the differentiation of its flowers at an earlier date than would one which blossoms late in the season. He states, however, that there is no exact correspondence between time of blooming and the time of differentiation. All varieties reach the same stage by the end of the autumn.

Season.

Bradford considers that the time of differentiation may vary from year to year, but only to a very slight degree. Luyten and de Vries (10) found that differentiation in the Pear took place slightly more early in 1922 than in 1923.

Position of the Bud on the Tree.

Goff found that the time of differentiation of the fruit buds of the apple occurred at two periods—in July and in September. Magness (15) discovered that axillary fruit buds commenced differentiation one month later than did spur fruit buds. Bradford went further and examined terminal fruit buds and buds from different classes of spur. He placed the spurs in four classes :—

1. Spurs on two or three year old wood forming fruit buds for the first time.
2. Spurs bearing fruit during the current year.
3. Spurs which have borne fruit formerly but not bearing in the current year.
4. Spurs which have borne blossoms but which failed to set or carry the fruit.

The buds formed on spurs in Classes 2 and 4 showed considerably more variation in time of differentiation than did those in Classes 1 and 3, differentiation taking place right up to the end of August in the Classes 2 and 4. Class 3 showed the most regularity. The terminal fruit buds, i.e., those borne at the extremity of the one-year-old long-shoots were found to be one month later in time of differentiation than the fruit buds on spurs of Class 3.

Cultural Treatments.

Kirkby (14) notes an earlier differentiation of fruit buds in apples growing in sod than in the same varieties in cultivated soil.

From the above considerations it can be seen that a rigid date cannot be given as the time for the change of the vegetative into the fruit bud. The factors causing this variation are variety, season, the position of the bud on the tree and the cultural treatments.

II.—INVESTIGATIONS AT LONG ASHTON.

In December, 1923, when the writer was at the East Malling Research Station as a post-graduate student, an investigation of the blossom bud development of the plum (*Prunus domestica*), was commenced at the suggestion of Mr. R. G. Hatton. The varieties Victoria and Cambridge Gage were selected and material was examined at intervals from December 1st until the time of the expansion of the blossoms. Thus it was possible to observe the stage at which

the bud had entered the winter rest period and also to trace the origin and development of the pollen grains and ovules. On arrival at Long Ashton in July 1924, the work was continued and the observations were repeated in the season 1925-26. Thus the complete development of the flower buds was followed for two seasons. An account will be given here of the results obtained in the two seasons 1924-25 and 1925-26.

Material and Methods.

In 1924, it was decided to use more than one variety for the investigation. The number had of necessity to be small owing to the large amount of labour that would be required to examine any number at all thoroughly. The varieties selected were Victoria, Pond's Seedling and Monarch, all widely grown commercial varieties and having quite distinct blossoming seasons, Monarch being early in flower, Victoria mid-season and Pond's Seedling late. These varieties also covered a fairly wide range in fruiting season, the fruit of Victoria ripening first and that of Monarch last.

In the foregoing review of previous research on the time of blossom bud differentiation it has been seen that the time of differentiation varies in any one variety according to the position of the bud on the tree, e.g., one on a short spur is differentiated quite a month earlier than that occupying the terminal position on a long-shoot. Hence in this investigation it was necessary to take buds from only one part of the tree, and those on short spurs of not greater length than four centimetres found on wood two years old, were used. If the branch of a plum tree is examined it will be found that blossom buds may occupy several positions. The majority are to be found on spurs of various lengths which are borne on wood of two seasons growth or wood of greater age. In addition, however, flower buds may also be found on the growth of the season just past—i.e., terminal or leader growth. In other words axillary buds on long shoots may be blossom buds. It will be noticed that in some cases two or three buds are to be found at some of the nodes on these long shoots. If three are present the central one is generally a vegetative bud and those on either side of it are flower buds. If there are only two, one of these is a vegetative and the other is a flower bud. These buds which are found at the side of the usual vegetative bud are sometimes known as " stipulary eyes " and the number which develops seems to vary with the variety. In Victoria generally only one develops (Plate III., Fig. 3), in Bittern two of them and in such varieties as Cambridge Gage none of them. If, however, in the last case the shoot is examined carefully a slight protuberance can be seen on either side of the vegetative bud showing that the " stipulary eyes " are there but have not developed.

Flower buds can be distinguished from vegetative buds in the winter before they they begin to " show white " by their rounder shape and smoother, less

hairy bud scales. They also have a less ragged appearance on a flower bud. If a number of spurs are examined in the winter it will be found that some have a terminal bud which is vegetative while on others the terminal bud is a flower bud, a difference not to be detected earlier in the season. In order to avoid inadvertently preparing an unnecessarily large number of vegetative buds for microscopical examination, terminal buds of spurs were never used, but only lateral buds from spurs of not greater length than four centimetres. The buds were always obtained from the same tree.

Sufficient spurs having been gathered from which to obtain twenty buds, the other scales of the buds were removed in order to facilitate penetration by the fixing solution and then the buds were placed in Gilson's fluid. It was found necessary to exhaust the buds of air to obtain successful penetration by the fixing solution. The buds were later washed, dehydrated and imbedded in paraffin in the usual way. Xylol and chloroform were both used as a solvent for the paraffin wax and gave equally good results. Sections were cut with a rocker microtome and stained in Delafield's Hæmatoxylin. For convenience the changes which took place in the flower bud of the variety Pond's Seedling will be described in detail and the development of the others compared with this.

Observations for Season 1924-25.

The first change which was noticed was a flattening of the growing point. This had taken place by August 6th. By August 18th to 27th the separate flower primordia could be seen and the calyx primordia were differentiated by September 10th or 19th. The primordia of the petals were visible by September 19th and those of the stamens by October 3rd. The pistil could also be seen on October 3rd, the ovarian cavity being well developed by November 4th. The sporogenous tissue of the anthers could be distinguished before the end of the year. The pollen mother-cells underwent division early in February and individual pollen grains could be distinguished by February 16th. The pollen grains were protected by a thick hyaline wall and the anther walls were completely differentiated by March 13th. Ovules were visible early in February. The first flowers opened on April 2nd. From this it will be seen that all the flower parts, the calyx, corolla, stamens and pistil are formed before the winter sets in. Increase in the size of the flowers was temporarily arrested from November until February, and the pollen grains and ovules were not formed until early in the next year. Sporogenous tissue could be recognised in the anthers in December. The pollen mother-cells developed rapidly in January and soon a prominent nucleus could be recognised in each and division soon followed. Ovules could occasionally be seen in December in an early stage of development, but generally they were not formed until January or February. The process

of differentiation in the variety Monarch followed that of Pond's Seedling very closely, being perhaps a little later in the early stages. The differentiation of Victoria flower buds, on the other hand, was slightly in advance of that of Pond's Seedling, the calyx, corolla and stamens being formed more rapidly. All three varieties reached the same stage of differentiation before the dormant season set in.

Observations for Season 1925-26.

In 1925-1926 the work was repeated, buds being again obtained from the same trees and from spurs of the same class. This time, however, buds of a second tree of the variety Victoria were also examined. It was seen in the account of the development of the buds in the previous season that those of the variety Victoria passed through the early stages of differentiation more rapidly than did those of the other two varieties. Now the Victoria tree which had been selected differed in habit from the Monarch and Pond's Seedling trees, being of the same age but relatively much smaller and more fruitful, many short spurs being formed and little terminal growth being produced. Hence there was the possibility that the more rapid differentiation of the Victoria buds was due to the condition of the tree and not to any inherent difference in the variety. In order to test this a second tree was selected in 1925, the tree being very vigorous and making much terminal growth. (See Plate I.) For convenience the former tree will be called Victoria A and the latter Victoria B.

The complete data obtained in the two seasons is set out in tabular form on page 206. On referring to this table it is seen that the earlier stages in the differentiation of the flowers of all three varieties occurred earlier in this season than in 1924. This may possibly be accounted for by the different weather conditions prevailing, the summer months of 1924 being very overcast and wet and the corresponding period of 1925 being much drier and more sunny. The rainfall for the three months May, June and July at Long Ashton was 13.58 ins. in 1924, and 8.38 ins. in 1925, and the number of hours of sunshine recorded during these three months were 575 in 1924 and 748.6 in 1925. It will also be seen that the time of differentiation of the buds on both trees of Victoria was precisely the same. The earlier stages in differentiation of buds on both Victoria trees were again passed through more rapidly than in the other two varieties. The same stages were reached by all three varieties by early December as in 1924. Active changes again took place early in January as in the previous year, viz., the development and division of the pollen mother-cells, and the appearance of ovules in the ovarian cavity. The blossom expanded at an earlier date than in the previous season. The changes which took place in the buds of the variety Pond's Seedling are illustrated by means of photographs. (Plates II. and III.)

Table showing the Stages in the Differentiation of the Plum Flower Bud.
Seasons 1924-25 and 1925-26.

		Flattening of Growing Point.	Flower Primordia	Calyx.	Corolla.	Stamens.	Pistil.	Pistil Cavity.	Pollen Mother-Cells.	Ovule.	Division P.M. Cells.	Pollen Grains	Anther Walls Differentiated.	Tree in Full Bloom.
Victoria A.	1924	25/7/24	18/8/24	10/9/24	10/9/24	10/9/24	19/9/24	3/10/14	2/1/25	2/1/25	20/1/25	16/2/25	28/2/25	14/4/25
	1925	13/7/25	25/7/25 to 12/8/25	12/8/25	12/8/25	27/8/25	11/9/25	7/10/25	7/1/26	7/1/26	2/2/26	15/2/26	15/2/26 to 2/3/26	29/3/26
Victoria B.	1925	13/7/25	25/7/25 to 12/8/25	12/8/25	12/8/25	27/8/25	10/9/25 to 23/9/25	7/10/25	7/1/26	7/1/26	2/2/26	15/2/26	2/3/26	29/3/26
Pond's Seedling	1924	6/8/24	18/8/24 to 27/8/24	10/9/24 to 19/9/24	19/9/24	3/10/24	3/10/24	4/11/24	2/1/25	2/2/25	2/2/25	16/2/25	14/3/25	24/4/45
	1925	13/7/25	12/8/25 to 27/8/25	11/9/25	11/9/25	7/10/25	7/10/25	7/10/25 to 16/11/25	7/1/26 to 2/2/26	2/2/26	2/2/26 to 15/2/26	15/2/26 to 2/3/26	2/3/26	6/4/26
Monarch	1924	6/8/24	27/8/24	19/9/24	19/9/24 to 3/10/24	3/10/24	3/10/24 to 4/11/24	4/11/24	2/1/25	2/1/25	20/1/25	2/2/25	16/2/25	9/4/25
	1925	25/7/25	12/8/25 to 27/8/25	11/9/25	11/9/25	11/9/25 to 7/10/25	7/10/25	16/11/25	10/12/25 to 7/1/26	7/1/26	7/1/26	2/2/26 to 15/2/26	15/2/26	17/3/26

SUMMARY.

In both seasons the earliest signs of blossom bud differentiation could be seen in the period mid-July to early August.

In 1925, differentiation took place at a rather earlier date than in 1924.

The buds of the variety, Victoria, whether taken from a vigorous tree or from a dwarf tree passed through the early stages of differentiation more rapidly than did those of Monarch or Pond's Seedling.

The buds of all three varieties reached the same stage by November, when all the flower parts, sepals, petals, stamens and pistil were present. The ovules and pollen grains were not usually formed until January or February.

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DESCRIPTION OF PLATES.

Plate I.

Fig. 1. Victoria: Tree A.

Fig. 2. Victoria: Tree B.

Plate II.

Fig. 1. Pond's Seedling. Condition Aug. 12th, 1925. Showing flower primordia.

Fig. 2. Pond's Seedling. Condition Sept. 9th, 1925. The calyx and corolla are visible.

Plate III.

Fig. 1. Pond's Seedling. Condition Oct. 7th, 1925. All the flower parts are present.

Fig. 2. Pond's Seedling. Condition Nov. 16th, 1925. The pistil is well developed and the ovarian cavity can now be seen.

Plate IV.

Fig. 1. Condition Jan., 1926. The rudimentary ovule and pollen mother-cells can be seen.

Fig. 2. Condition Feb.—March, 1926. An ovule and pollen grains are present.

Fig. 3. Part of a terminal shoot of the variety, Victoria. Some so-called "stipulary buds" can be seen. Two of the solitary axillary buds are flower buds.

PLATE I.

Fig. 1.

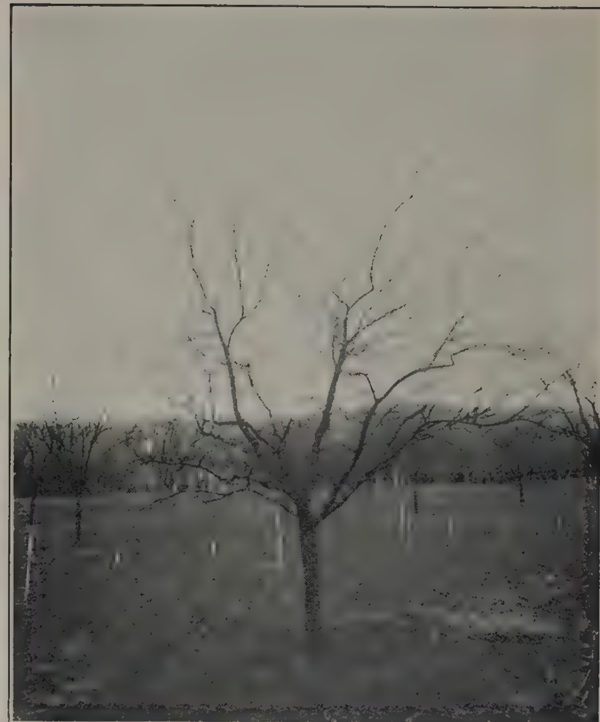

Fig. 2.

PLATE II.

Fig. 1.

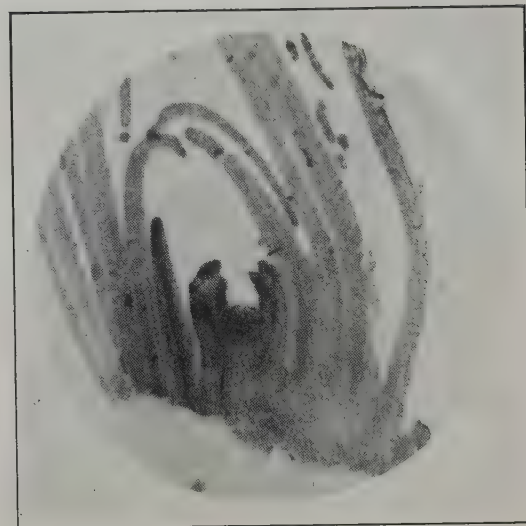

Fig. 2.

PLATE III.

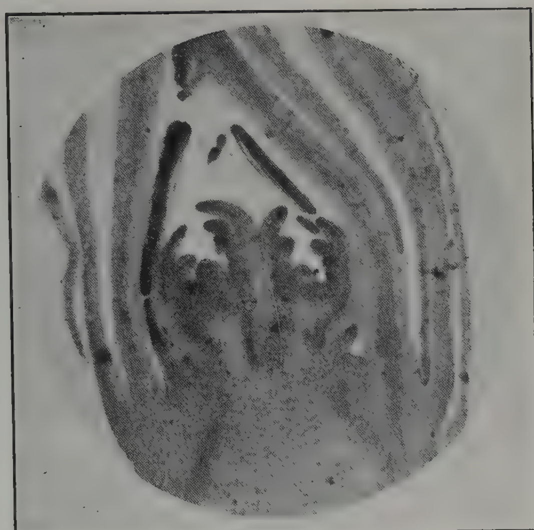

FIG. 3.

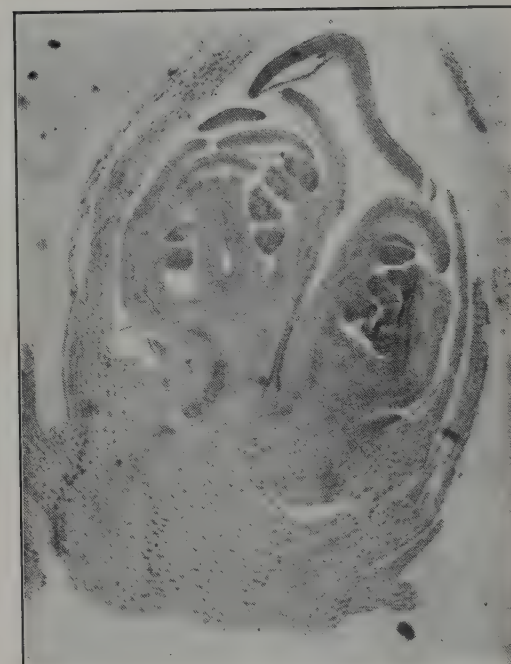

FIG. 4.

PLATE IV.

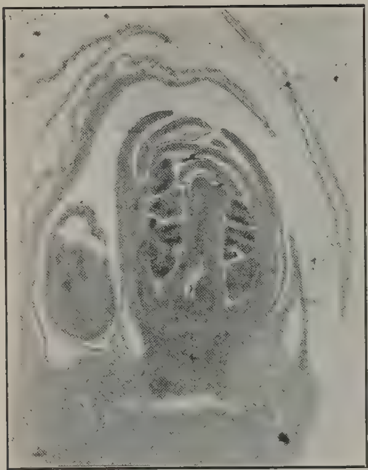

Fig. 1.

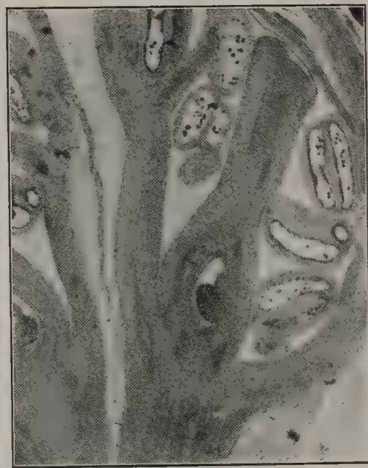

Fig. 2.

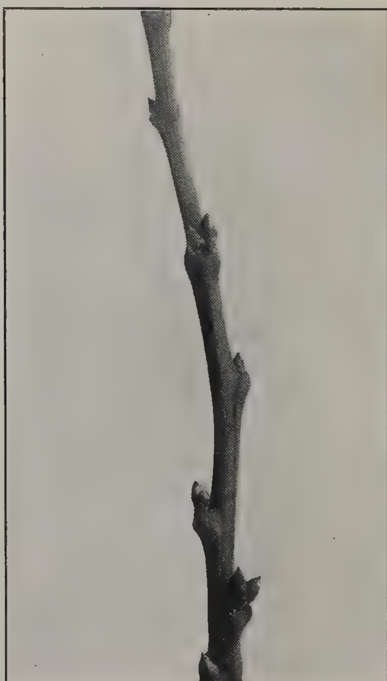

Fig. 3.

STUDIES ON THE RESISTANCE OF APPLE TO THE WOOLLY APHIS (*Eriosoma lanigerum* Hausm.)

By RICHARD LE PELLEY, B.Sc., A.R.C.S., D.I.C.

CONTENTS.

As the writer was interested in the Woolly Aphis, the late Professor H. M. Lefroy suggested in the autumn of 1924, that he should take up the work on the resistance of Apple Root-stocks to this insect, begun by Staniland and unavoidably interrupted by his appointment at Long Ashton. Professor Lefroy instigated the arrangement by which this was begun at East Malling in December 1924. The writer owed him thanks for suggesting the work and for the interest he took in the early stages.

The writer also wishes to express his indebtedness and thanks to Mr. R. G. Hatton for help throughout the course of the work, particularly on all pomological questions.

I.—REVIEW OF SOME FORMER WORK.

It has been known for many years that Northern Spy and Winter Majetin are varieties of apple immune from the American Blight or Woolly Aphis (*Eriosoma lanigerum* Hausm.). In certain parts of the world—for example Rhodesia (1)—legislation has been passed to prohibit the importation of apple stocks other than Northern Spy or those accepted as being resistant. Although the fact that certain apple varieties are immune, or highly resistant to this insect has been known for about a century, (this character in Winter Majetin is mentioned by Lindley (2) in 1831) until recently our general knowledge of varietal resistance has been chiefly obtained by observations of the extent to which different scion varieties are attacked by natural infection.

French, 1904 (3), gives a list of twenty varieties "proof against attack of Woolly Aphis," among which are Northern Spy, Winter Majetin and Irish Peach.

Huergo (Hijo), 1911 (4), gives a list of 268 varieties classified according to the degree to which they may be attacked in Argentina. He records seventeen varieties (among which are Northern Spy and Neidwetzkiana) as immune (*inatacables*); fifty varieties (among which is Duchess of Oldenburg) as little attacked (*poco atacadas*); ninety-eight varieties (among which are Allington Pippin, Cox's Orange Pippin, and Prince Albert) as fairly heavily attacked (*basante atacadas*); and seventy-six varieties (among which are Bismark and Beauty of Bath) as very heavily attacked (*muy atacadas*). He also gives lists of apples recorded by other writers to be resistant.

Theobald, 1921 (5) gives a list of varieties of apple grown commercially in England with growers' reports of the extent of attack on them.

Cole, 1922 (6) describes two varieties in Victoria, Australia, that are said to be immune. One of these is said to be a cross between Winter Majetin and Jonathan.

Bremer, 1922 (7) advocates the use in Argentina, of stocks resistant to Woolly Aphis.

Speyer, 1923 (8) gives a list of fourteen varieties (among which is Zuccalmaglio Reinette) that have shown good resistance in the Prussian province of Saxony, and a list of varieties (among which is Cox's Orange) regularly attacked. The same writer gives longer lists in 1924 (9) of the amount of attack which may occur on different varieties.

Jegen, 1924 (10) stresses the opinion that climatic and soil conditions may influence the degree of resistance of a variety. He gives preliminary results of a small number of infection experiments on scion varieties, which partly conflict with the results of other workers. Doubtless in the case of Cox's Orange Pippin (for example) on which he did not induce colonies, a larger number of artificial infections would have shown it to be susceptible, as it is accepted to be by other writers.

Staniland, 1923 (11) published an account of the first extensive infection experiments with Woolly Aphis. These were carried out mainly in London. Up to that time our knowledge on this subject had been almost entirely confined to observations on scion varieties. Staniland's work gave the first knowledge on the resistance of Root-stocks. He tested the resistance of the East Malling selections of "Paradise" Root-stocks, as well as of several other series of stocks. His experiments showed that, of the stocks tested, few possessed a high degree of resistance.

II.—OBJECTS OF THE WORK.

The present investigations were begun with four chief objects in view.

1. *To test the resistance of commercial root-stocks.*

It was thought that some of the types of stock without particular merit, might prove so susceptible that their cultivation, except for special purposes, could with advantage be discontinued. A more important object was to discover if any commercial stocks possessed a sufficiently high degree of resistance to be recommended because of this character. If a susceptible variety is worked on an immune stock, there can be no migration from roots to scion, and hence a recurrent danger is avoided, making it more easy to keep the tree free from the pest, because the insect is more easily destroyed above ground than below. This is, of course, the reason for the Root-stock import restrictions overseas, to which reference has been made. Another advantage of immune stocks is that they will be free from the pest when propagated, and there will be no dissemination of the pest from the nursery.

2. *To test the resistance of scion varieties.*

The object of this test was to discover if any of a selection of varieties were sufficiently resistant to be chosen for commercial purposes where Woolly Aphis was known to be serious; or to be recommended for top-working on trees known to be heavily attacked.

3. *To test the interaction of stock and scion.*

This experiment was planned to attempt to discover whether the resistance of the stock has any influence on the resistance of the scion worked on it, or vice versa.

4. *To test new seedlings (having Northern Spy for one parent) to discover whether the character of immunity could be transmitted.*

As all the Malling selections of "Paradise" stocks (13, 14) appeared to be more or less susceptible to the Woolly Aphis, and as the immune Northern Spy had proved to be a poor stock in this country (and was, indeed, reported to be none too satisfactory in some countries overseas where it was extensively used), breeding work was planned by Mr. Hatton and Mr. M. B. Crane of the John Innes Horticultural Institution, with the object of combining the character of immunity possessed by Northern Spy, with other desirable features of the Malling "Paradise" stocks, should it prove that the character of immunity could be hereditarily transmitted. The seedlings used in this test were all bred by Mr. M. B. Crane.

III.—METHODS AND TECHNIQUE.

A. OUTDOOR AND INDOOR CONDITIONS FOR TESTS.

It was at first planned that all the experiments should be carried out on material planted in the open, with a few plants from each, potted and kept in a greenhouse where they could be more consistently observed. Later it was found that, although special difficulties arose (these are described in section D of heading III) the use of indoor conditions could with advantage be considerably extended. Under glass it was possible to induce good infections on the plants, fully two months before the insect was active outside ; and the more controlled conditions (chiefly important of which was a less variable temperature) enabled the insect to multiply numerously and consistently from April till September, and so the plants had a far more stringent test than they could be given outside. Those plants which it had been impossible to infect, or which had proved highly resistant in the open in 1925, were brought into the greenhouse in the winter, and those that could not be infected under these conditions throughout 1926 were considered immune. The particular value of this test will be realised when it is stated that, although frequent artificial infections were made on these plants, they were hardly necessary because the infection was so heavy in the house that at almost any time during the summer numerous aphids could be found walking about on all the plants.

B. MATERIAL USED.

1. The commercial root-stocks tested were all one-year layered shoots which had been transplanted from the "stools." In the open they were planted 1 ft. apart with 2 ft. separating different types. In the greenhouse they were in pots, as was all the other material tested under glass.

2 and 3. In the commercial scion variety test, and in the interaction of stock and scion test, all the material was worked on stocks planted in the open at 6 inches apart. One foot separated different varieties. They were budded (or grafted where necessary by the dying of a bud) 3 or 4 inches above ground level. This is higher than in commercial practice in order that the union should be easily visible, and that the stock could become infected above ground and so more easily form a source of infection for the scion.

4. The hybrid material bred by Mr. Crane formed two distinct groups, (a) original seedlings which were all four- to five-year-old trees when the tests were carried out, (b) layered shoots from other seedlings which had been propagated at East Malling. The layered shoots were planted close together (6 ins. separating stocks with 1 ft. between those from different seedlings) in the open.

The unit of 10 was chosen of most of the stock and scion varieties tested in the open, and usually a unit of 4 of each was tested at the same time under glass.

C. Artificial Infection.

An old Bramley's Seedling tree in a neighbouring orchard supplied the first material for infection purposes. At first it was hoped that it would be possible to work up a stock early in 1925 from a single apterous parthenogenetic female, such as are found on the apple throughout the year. Attempts soon proved that this would take more time from the infection season than was justified; so a heavy attack was induced, with ten or fifteen insects from the Bramley tree mentioned, on a Cox's Orange Pippin under glass. From this a stock was worked up on Cox, Allington and Beauty of Bath, three very susceptible varieties.

(i.) *Protection of Infections.*

At first artificial infections in the open were made without protection of any sort; this proved unsatisfactory—insects were often seen to be blown off by wind, and occasionally washed off by rain before they had settled down, and only a few infections produced colonies. Two other methods were then tried. A wooden frame covered with muslin, big enough to hold ten stocks, was placed over stocks that had been infected. This did not prove so successful as a small sleeve of muslin covering just that part of the stock on which an infection had been made, probably because the protection of the cage was less adequate than that of the sleeve. The following are the figures of the number of successful infections induced by each of these methods in one experiment before August 5th 1925:—Thirty-one successes out of 172 open infections; fourteen successes out of thirty-four caged infections; seventeen successes out of twenty sleeved infections. It should be stated that these figures are not strictly comparable because although they are of infections made by each method at about the same times, and in the cases of the open and sleeved infections on the same eleven types of stock, the caged infections were only made on five of the types. It was considered, however, that these figures indicated sufficiently surely that the sleeve method was the most satisfactory. In 1926 calico sleeves were used instead of muslin. These were more durable and proved still more efficient, as they gave more protection from both rain and wind. They were usually removed after ten days, by which time the insect had had time to settle down. The plant was nearly always unharmed by having been partially enclosed for this short time.

(ii.) *Method of Making Infections.*

Great difficulty was experienced before a satisfactory method of making infections was devised. At first both in the open and under glass, it was decided to start the infection on each stock with one insect. For this purpose insects were brushed into a small glass dish and transferred singly to the stocks. The numerous failures to produce any colonies by this method were almost certainly due to damage caused to the insects' stylets when brushing them from their

original feeding place. The insects were then removed one by one under a binocular microscope, by teasing them with a needle, until they withdrew their stylets. This proved far too laborious a method for generous use, but many infections in 1925 were started with single insects removed by this method. The method which then suggested itself was to pick off with a brush those young insects that are always to be found walking about a tree that is heavily infested. Using ten or twenty of these young insects on each stock in the open, most of the successful infections were made during 1925.

This method, however, proved too slow and uncertain to be employed for the large number of infections that had to be made in 1926. Small pieces of shoot bearing good colonies were cut and placed in pill boxes. A fairly high percentage of the large insects died, but after three or four days many reproducing females had left the twig and were wandering about with the very numerous young that had never settled down. These were removed with a camel's hair brush and placed directly on the stocks it was desired to infect. By this method, using a fairly large number of insects for each plant, in the open, many successful infections could be quickly made. A less troublesome, and still more expeditious method, however, was found to be to place small pieces of attacked twigs in the calico bags already described and allow the insects to walk off and infect the stocks themselves. This method was found to be extremely successful; very few failures to produce infections by this method were recorded, except on some of the most resistant plants.

The artificial infections were made when possible on soft new growth. This was found throughout to be the most easy part of the plant to infect. Young transplanted layered shoots were more easy to infect than older plants, and very much more easy than the seedling trees, which were found difficult to infect in the open. Cracks in old wood on stocks and trees often became infected, but these places were not used for artificial infections. Wounding the shoot to be infected was only used in attempts to infect highly resistant stocks, on which it had been impossible to induce colonies without.

With the exception of the experiment in which the different methods of protecting colonies were compared, early in 1925, similar infection methods were used for each different experimental series.

(iii.) *Method of Making Root Infections.*

Although comparatively little was done on Root resistance, the technique will be described in some detail as it proved satisfactory. In pots the root was exposed by digging a small pit. When the Aphids had been placed on it with a camel's hair brush they were covered with soil to a depth of $\frac{1}{4}$ to $\frac{1}{2}$ an inch. Above this an inverted watch-glass was placed, and the rest of the pit dug to expose the root was filled in with soil. The watch-glass served two purposes;

it prevented the insects being flooded out by the watering before they had established themselves on the root, and it enabled the exact position of the place of infection to be ascertained for examination. When the watch-glass was lifted out a very slight displacement of the soil under it exposed the root.

In the open the method used was the following. A trench about 6 inches wide and from 4 to 6 inches deep (or as deep as necessary in any particular case) was dug parallel to, and about 1½ inches away from, a line of as many stocks as it was desired to infect. Ground was then carefully scraped away to expose some roots on the side of the trench. Infections were made on these. A sheet of glass (wood would be as effective) was then placed along the side of the trench as close to the stocks as possible without disturbing the infected roots. The trench was then filled in; and the space between the stocks and the glass (containing the infected roots) was also carefully filled. For examination the trench outside the glass was again dug, the glass removed, and it was then easy to displace the soil round the roots. These methods very nearly preserved the natural conditions.

D. Control of Apple Pests.

During the course of these investigations several technical difficulties such as the control of pests other than the Woolly Aphis, which adversely affected the health of experimental plants, had to be studied. Future workers on this problem are likely to have similar troubles and it is thought that a very short summary of methods employed, with indications of how far they were successful or impracticable, may be of use.

(i.) *Indoor Pests and Methods Employed.*

The chief trouble during 1925 in the greenhouse in which the indoor tests were carried out was an attack of Red Spider. The mites spread rapidly and before observations on the stocks had been completed they became too well established to be controlled. It was realised that a bad recurrence of Red Spider in 1926 was almost certain unless the house were thoroughly cleaned during the winter. From the work of Speyer (20) on the control of Red Spider in cucumber houses, it was clear that an application of Napthalene would be of use. A heavy application of Naphthalene was made late in autumn and as far as was observed all the mites were killed, though some eggs may have survived the treatment. It was interesting that although the application was extremely heavy and lasted for about forty hours with the temperature between 70°F. and 90°F. a large percentage of the Woolly Aphids recovered.

Although a very general and heavy attack of Red Spider in 1926 was doubtless prevented by this fumigation, an attack began early in the year on some of the Woolly Aphis resistant trees that had to be brought in for final testing.

Measures were taken to control it as soon as it appeared, and the spray described by Lloyd (21) composed of 9 oz. of flour and 6 oz. of potassium sulphide in 12 gallons of water was applied. It was found possible to keep the Red Spider in check by periodic sprayings with this wash without unduly disturbing the colonies of Woolly Aphis. Between April and September nine applications were made. The Red Spider was thus confined to the side of the house on which it first appeared and the stocks of Table 2 were not attacked.

Mildew. The next most serious trouble during the spring and summer was Mildew. For the control of this Ammonium polysulphide 1 part to 100 parts of water was used. Three applications of this were made in April and May, the last of which caused some scorching of leaves. Two sprayings with flowers of sulphur and soft soap were made in June and July and these were the last necessary against Mildew. They left a deposit of sulphur on the leaves and stem but this had no appreciable effect on the Woolly Aphis which went on increasing very prolifically during this period of the summer.

Apple Aphids. The other chief pests were the Green Apple Aphis (*Aphis pomi* DeG.) and the Rosy Apple Aphis (*Aphis sorbi* Kalt.). Caterpillars were being reared in part of the house during the summer and these pests were constantly and unavoidably brought in on the apple shoots on which they were fed. For the control of these fairly regular treatment with nicotine and soft soap was necessary. At first all the plants were sprayed, but when the colonies of Woolly Aphis became large the shoots infected with *Aphis pomi* were dipped in a bucket of the spray and afterwards shaken. This was a more laborious method but it had the advantage that the Woolly Aphis was less disturbed. Between April 14th and May 28th ten applications of nicotine and soft soap were recorded; after this records were not kept but the treatment went on throughout the summer.

(ii.) *Influence of Sulphur Treatments on Experimental Results.*

It is certain that the three sulphur treatments employed (and particularly the one of soft soap and flowers of sulphur which left a deposit of sulphur on the plants for a long time) did have an influence throughout the summer on the health and rate of reproduction of the Woolly Aphis, because a small amount of sulphur vapour must usually have been present in the house. If the figures of Table 2 purported to be the intensities of attack produced on each stock by one female the above treatments could not have been applied. But as there was a great deal of cross infection it is pointed out in the discussion on the Table that the attacks were as heavy as possible under the prevailing conditions; and the slight effect the sulphur must have had may be neglected, because no differences in resistance are considered to have been shown unless the figures are so far different as to exclude the possibility of another interpretation

being placed on them owing to considerations of experimental error. Such a well marked difference is that between Crab H and the other stocks tested. Without these stringent control measures against pests, none of the valuable tests under glass would have been possible during the year. The growth of plants which had received several applications of two of the sulphur treatments (polysulphide and flowers of sulphur) will be seen in the Plate.

(iii.) *Outdoor Pests and Methods Employed.*

The chief pests in the open were *Aphis sorbi* and *Aphis pomi*. In 1926 both these pests were present in large numbers and several sprayings with nicotine and soft soap were necessary to control them. However, they were not a serious trouble after July, and it was after this month that the most successful infections with Woolly Aphis were made.

Predatory Coccinellidæ. The chief trouble in 1926 was from predatory Coccinellidæ. In 1925 although an occasional Syrphid larva was found preying on the Woolly Aphis no predator was serious, and heavy and flourishing attacks existed undisturbed until the end of October.

In 1926, however, great trouble was caused by Coccinellidæ. The insects concerned were chiefly *Adalia bipunctata* L., *Coccinella variabilis* L., with a few *Coccinella septempunctata* L. During July an odd ladybird was occasionally seen eating a colony of Woolly Aphis. All those seen were immediately killed. On Sunday, July 25th, several Coccinellidæ were seen on some Type I. stocks which were heavily infected with Woolly Aphis. These were killed. On Monday and Tuesday small numbers were collected, but by Tuesday they had shown no signs of being a serious factor in the continuation of the Woolly Aphis. On Wednesday, July 28th, a large number of insects were found on the experimental stocks, many of which had been rapidly stripped of Woolly Aphis. The stocks were carefully examined and all the ladybirds that could be found were collected. Many were found in old leaves formerly curled by Rosy Aphis. About 600 adult ladybirds were collected on this day, and though it was quite impossible to bag all the infected stocks, some of those most heavily covered with Woolly Aphis were bagged, in order that insects for infection purposes would be available, because it was then realised that the sudden large influx of ladybirds might wipe out the Woolly Aphis entirely. Daily collections of ladybirds were made for six weeks after this, and altogether very large numbers were captured.

This was not an isolated example ; several reports of similar and concurrent visitations of these predators in different parts of Kent were received. One orchard in North Kent known to be heavily attacked by Woolly Aphis, was visited on July 29th and Coccinellids were found preying on most of the colonies of Woolly Aphis still present. The orchard which had been heavily attacked ten

days before was almost clean. It is obvious that ladybirds may in some years be a distinct check to the Woolly Aphis.

In experimental work in the open, it is necessary to prepare for the possible destruction of colonies by these insects. If the work is being done on a large scale it will not be possible to cover all infections, but the writer suggests that some susceptible stocks should be reserved entirely for infection purposes, and covered with fairly wide mesh wire gauze cages, kept ready for the purpose, on the first sign of the presence of predatory Coccinellidæ. This will not make the daily collecting of insects, in such an attack as occurred during these experiments, unnecessary ; but it will ensure a stock of aphids for artificial infections.

IV.—MEASUREMENT OF RESISTANCE.

A. General.

It may at once be stated that no quite satisfactory method of measuring differences in degrees of resistance has been devised. Differences that seem quite obvious in practical work with the stocks in the field (as the difference between Type II. and Type XIII.) are difficult to translate into figures which are significantly different when examined statistically. The only published account of any method of estimating resistance the writer has seen is that of Staniland (10). This is on the galling of the plant. It will be shown that though this is a factor to be considered, it has not proved an entirely satisfactory criterion in the present experiments.

It is here necessary to define Resistance, so that the sense in which it is used, in the following descriptions of methods employed in the attempt to decide the degrees of resistance possessed by different varieties, will be clear. The degree of resistance of a plant to the attack of an insect may be defined for practical purposes as the degree of the power possessed by the plant to influence the ultimate amount of damage that the insect can do to it. Based on this definition an Immune plant is one whose normal growth cannot be damaged by the insect ; a plant with a high degree of resistance is one whose growth can be little damaged by the insect ; and a plant with a low degree of resistance is one whose growth can be much damaged by the insect. The terms " Resistant " and " Susceptible " are used as convenient means of distinguishing plants which have respectively a high degree of resistance and a low degree of resistance.

Theoretically a true knowledge of the resistance of a variety could be obtained by a comparison of the growth it made when attacked by the insect, and that made when free from the insect, under conditions in all other respects the same. This, however, is not possible in practice. When for example it is necessary to estimate the resistance of an individual seedling, if it be infected there is no means of knowing what its normal growth would have been ; and it is clear

that though it may be highly resistant, it may make very poor growth owing to having been poorly rooted or unhealthy in some other way. Then in cases where numbers of a variety are available it would be necessary for the numbers used to be so large, in order that other influences besides the attack of the insect should not mask the final result, that it would be impracticable to test more than a few different varieties at a time.

When a plant is attacked by a parasite the ultimate growth of the plant is the resultant of the complex of activities set up by the actions of the parasite, the reactions of the host, and the influences of the environment on both host and parasite and their reactions to it. As we cannot use the growth of the plant as a measure of its resistance, it is necessary to find some other measurements or observations which it is justifiable to assume will give, though not an exact measure, at least a close approximation to the actual degree of resistance existing.

If we measured one reaction of the plant, such as the size of gall produced, it might be so closely correlated with the resistance, that it would afford a tolerably good measure of it ; on the other hand in such an isolated reaction, differences might occur which could not be considered as indicating equal differences in resistance. A large number of galls on different stocks were measured and the mean size for each stock calculated. Actually the figures used were the diameters of galled portions of stem expressed as percentages of the diameters of the corresponding ungalled portions above or below. The figures (Table III.) show very clearly that there are definite differences in the mean size of galls produced by different types of stocks which do not indicate proportional differences in resistance. Crab H, which other observations very definitely prove to be more resistant than most of the types tested, produces very large galls in a very short time ; and the mean size of gall on this stock is higher than that on many stocks known to be very much more susceptible. We must conclude, therefore, that this characteristic reaction of the plant is only one of the factors to be considered in the endeavour to estimate degrees of resistance.

If we measure the intensity of attack (for example by counting the number of insects produced) we are measuring not an isolated reaction, but the ultimate effect on the insect of the complex of interactions of host, parasite, and environment, to which reference has already been made. It cannot be considered that this is necessarily the inverse of the ultimate effect on the plant, because it is conceivable that, say, 80,000 insects would do less damage to one variety than 70,000 would to another. It would certainly usually occur that a vigorously growing stock would support the same number of insects with less damage than would a less vigorous one. But the success of the insect in productivity is undoubtedly closely correlated with the failure of the plant to make good growth.

By means of infestation figures obtained by counting the number of insects produced on different varieties of *Vicia faba* under controlled conditions Davidson (15) has been able to show definite differences between certain of these varieties in their degrees of resistance to *Aphis rumicis*.

If we assume that the number of insects produced on a stock at the height of an infestation would give the best indication of the resistance we are at present able to obtain, a practical difficulty at once arises owing to the huge numbers of insects that would have to be counted. The number of insects supported by a stock one year off the layer may be as many as 100,000. The compromise adopted was to estimate the intensity of infection with no direct reference to the number of insects present. The very rough method used in the open was the arbitrary one of allotting a number, from one to five, to represent different intensities of attack. Under glass a more accurate method was used. The percentage area of the plant attacked was estimated by measuring the amount of growth that was covered with colonies and calculating it as a percentage of the total growth present. It was generally sufficient to consider a shoot either as completely surrounded by insects, as often occurred, or as half surrounded which was also very common. When a shoot was half surrounded, the attacked side was nearly always the underside, even when the shoot grew at only a few degrees from the vertical. In order to have a rough idea of the number of insects likely to be present in every inch of a heavily attacked shoot, several detailed counts were made. The following are typical examples.

Type I., 3.2 inches of shoot	6,578 insects supported.
Type I., 1.3 inches of shoot	2,180 insects.
Type I., small spur	665 insects.
Type III., 2.2 inches, not completely surrounded	2,838 insects.
Cox's, 1.4 inches of shoot	2,987 insects.

The average figure of 2,000 insects per infected inch of a shoot heavily attacked may be nearly correct. A thick stem will support more and a thin shoot less. Every inch of plant completely surrounded by insects was called 2, and every inch half surrounded was called 1. The total (very roughly the number in thousands supported by the plant) was worked out as a percentage of twice the total growth of the plant.

From a practical point of view these estimates are sufficiently satisfactory because a grower is not concerned with a difference of, say, 10 per cent. between two susceptible stocks. Before one stock will be chosen, for commercial purposes, instead of another, owing to its superior resistance to Woolly Aphis, the difference in their degrees of resistance must be very definite and obvious.

One other factor not yet mentioned that may have to be considered in estimating resistance is the difficulty of inducing a colony to establish itself. In the case of Crab H, although colonies quickly produce large galls when once established, the stock was more difficult to infect during the experiments than most others. In the open in 1925 the first six artificial infections, from June till August, failed to produce colonies on most of the ten stocks of Crab H, whereas two or three were usually sufficient to infect other types of stocks.

B. Resistance of Northern Spy.

Before giving the results of the series of infection experiments, a somewhat detailed account of the resistance of Northern Spy will be given, both because it has a bearing on the theoretical questions regarding the measurement of resistance, and also on the practical means of estimating that of very highly resistant varieties. This latter bearing will be referred to again later in this paper. Ten stocks of Northern Spy were planted in the open in 1925 ; two small trees were kept under glass in 1925 and 1926 ; and four potted stocks were also kept under glass in 1926. Besides these, on all of which artificial infections were carried out, about sixty were used as stocks for maiden trees infected in another experiment (number 3.)

Attempts to induce permanent colonies on the Northern Spy stocks and trees were unavailing, but the insects often lived on them for several weeks. One individual insect was observed to live on a shoot of Northern Spy with its stylets inserted for more than five weeks, without producing any young (so far as was observed) during this period. In 1926 when infections were "taking" particularly well, four of the Northern Spy stocks in the open were wounded, and several thousands of aphids were placed in each bag surrounding the wounded portion. The infections were made on August 23rd and were left until October 5th. On this date, on each stock, about twenty or thirty insects in a small group were living at the edge of a wound. Attempts were also being made to settle down elsewhere, but when the bags had been removed a week they all proved to have been abortive. This is typical of what occurs on Northern Spy. The number of insects alive and grouped together gives the look of a small colony, but they never produce a good covering of "wool" and as far as it was possible to observe, never reproduce on the stock. No trace of galling has ever been observed and no abortive attempts to produce colonies, as described above, have been seen under natural conditions, though they doubtless occur on occasions.

In artificial infections of the roots of Northern Spy, Becker (19) obtained temporary colonies in a few cases ; but in no case did he succeed in getting permanent colonies established. He remarked on the sickly condition of the temporary colonies on Northern Spy.

Northern Spy has been used in the function of a "control" in all the present experiments. This was particularly useful in arriving at a conclusion about the resistance of some of its own seedlings. Theoretically, since insects can live for some time on it, Northern Spy should not be referred to as immune but as very highly resistant; and where the word "immune" is used in this paper it is intended (unless otherwise stated) to mean "immune for all practical purposes," and to represent a degree of resistance equal to that of Northern Spy. For all practical purposes, Northern Spy has proved in these experiments to be Immune, as has been stated by other writers, and proved in commercial practice in various parts of the world, because no damage has been seen on it under natural conditions, nor indeed any measurable damage under the stringent conditions of artificial infection described.

V.—EXPERIMENTAL RESULTS.

1. Commercial Root-stocks.

(i.) *In the Open.*

The stocks tested were ten types of the Malling selections of Crab and "Paradise" stocks, and Northern Spy.

Infections were started in June and had begun to increase in most cases by July. The dates of infections on each individual were recorded and periodical examinations enabled a record to be kept of the date when a colony was seen to have "taken." This recording of the infections on each individual plant was done in all the experiments. A complete examination and estimation of the intensity of attack was made on October 28th, when attacks were at their height. The estimation was made by allotting for each stock a figure from 1 to 5, the signification of which may be shortly described as follows:—

1. Slight attack, one or a few small colonies.
2. Some fair-sized colonies.
3. Large colonies accompanied usually by galling.
4. Heavy attack, many large colonies.
5. Very heavy attack, long stretches of old and new wood covered by continuous colonies.

The following table gives the number of stocks of each type on which an infection had become established by October 28th, and the individual condition of each on this date.

TABLE I.

Stock.	Malling designation	Number artificially infected.	Number of infections taken by Oct. 28.	Estimated individual intensity of attack on October 28th.	Average intensity.
Crab Selected Seedling (Malling)	Crab A.	10	10	1, 2, 3, 3, 3, 3, 3, 3, 4, 4	2.9
Crab ditto	Crab C.	9	7	1, 1, 5, 3, 2, 1, 2	1.7
Crab ditto	Crab F.	8	6	3, 1, 2, 5, 3, 2	2.0
Crab ditto	Crab H.	9	9	1, 1, 1, 1, 1, 1, 1, 1, 1	1.0
Broad-leaved English Paradise ..	Type I.	10	10	5, 5, 5, 4, 5, 5, 5, 5, 5, 5	4.9
Doucin	Type II.	10	9	4, 2, 3, 4, 4, 4, 5, 5, 2	3.3
Holstein Doucin ..	Type IV.	10	10	3, 3, 5, 5, 4, 4, 5, 5, 2, 5	4.1
Jaune de Metz ..	Type IX.	10	10	3, 4, 2, 2, 2, 2, 2, 3, 2,2,	2.4
Selected Seedling (Malling) ..	Type XII.	10	9	5, 5, 3, 3, 5, 4, 5, 2, 3	3.5
Selected Seedling (Späth)	Type XIII.	10	3	1, 3, 1	0.5
Northern Spy ..		7	—		—

The table exhibits several interesting features. Type I. (Broad-leaved English Paradise) was the most heavily attacked. Apart from Northern Spy, Type XIII. had the lowest number of individual stocks attacked, but one of these merited the figure 3 to describe the attack on it. In the case of Crab H. the colonies were all slight (figure 1 in each case). The most that can be deduced from the table about the other stocks is that they are all susceptible. In the cases of Crab C. and Crab F. where the average figures for intensity of attack are low (1.7 and 2.0) one of the individuals was heavily attacked (figure 5), which suggests that they cannot be considered to have a higher degree of resistance than some of those with a higher average figure.

The differences recorded in the intensity of attack on individuals produced by vegetative propagation from one type of stock, are considered to be due, not to hereditary differences in resistance, but either to accidents of infection (such as differences in the dates when artificial infections were first induced on them) or, possibly, to differences in the condition (health) of the plants during the time of attack by the insect. Errors in estimating, of course, also play some part. Orton (18) differentiates between disease resistance which is heritable, and disease endurance, which " sometimes results from the ability of the plant to grow in spite of an attack, either through exceptional vigour or through

a hardier structure." It is clear that a certain number of insects on a small stock will cause a more heavy attack than the same number on a vigorous one and will be estimated with a higher figure. This does not necessarily mean that a weakly plant is more suitable to the insect than a healthy one, and in fact Davidson (16) found that there was no support, in the case of Beans attacked by *Aphis rumicis*, for the usual opinion that weakly plants are more heavily attacked than healthy ones. No experimental evidence was sought on this question, in the case of Woolly Aphis on apple; but a unit of 10 of Type XIII., planted in 1926, which became infected before they were well established, did become a good deal more heavily attacked than any others of the same type observed in the open. It seems therefore that in the case of Woolly Aphis on Apple, differences in intensity of attack occurring within one variety may prove to be due partly to fortuitous differences in the vigour or health of the plants during the period of infection, the less vigorous plants possibly being the more heavily attacked.

For practical purposes, however, a type of stock, or a variety, is not likely to be selected because of its resistance to Woolly Aphis unless this resistance is sufficiently high to be maintained even under unfavourable conditions.

Although the growth of the plants was not used in the attempts to estimate resistance, it may be mentioned that there were great differences in growth between some of the above stocks in 1926. The stocks of Type I. were very unhealthy, made very poor growth and some of them died, while Types II. and IV. also made poor growth. The units of IX., XII., and Crabs A., C., F., made better growth than these; while in no case did a stock of XIII. or Crab H. show any noticeable ill effect due to the Woolly Aphis.

(ii.) *Under Glass.*

Under glass the following four Types, represented in each case by four potted stocks, were infected in 1925 :—Type I. (Broad-leaved English Paradise), Type IV. (Holstein Doucin) Type IX. (Jaune de Metz), Type XII.

Artificial infections were begun in May and heavy attacks were present by the end of July. On July 28th they were all examined and the attacks estimated.

Type	I.	4, 3, 5, 3.	Total, 15.
Type	IV.	3, 3, 3, 3.	Total, 12.
Type	IX.	2, 4, 5, 3.	Total, 14.
Type	XII.	5, 3, 2, 3.	Total, 13.

Type IV. had no higher figure than 3 recorded against it, but the colonies increased in size later. The four types are all susceptible.

Estimation of Intensity of Attack.

In 1926 it was decided to test all the Malling selections of " Paradise " Stocks. With the exceptions of Types XI. and XIV., which were not then available, they were all potted in units of 4, and were sunk in a cinder bed in the greenhouse. In a few cases the unit tested was slightly larger than 4 ; and in a few cases one of the stocks was used for some other purpose before the final examination, and so was not available for inclusion in the final figures.

Infections were begun on these on April 7th. Attacks were growing on most of them by the middle of May, and by the end of July the attacks were generally very heavy. The final examination and estimation of the percentage area attacked was made from September 11th to October 6th. It should be pointed out that this is not in any sense an examination of the amount of attack produced by one or any definite number of infections. When the insect had become well established the numbers were so great in the house that there was an immnese amount of cross infection, and the attacks may be taken to have been as heavy as possible under the conditions prevailing. The results of the final examination are expressed in the following table :—

TABLE II.

Stock.	Malling designation.	Number used.	Mean % Attack.
Broad-leaved English Paradise ..	Type I.	5	63
Crab Selected Seedling (Malling) ..	Crab C.	4	61
Crab ditto	Crab A.	4	61
Selected Seedling (Späth)	Type XVI.	3	61
Doucin	Type II.	4	56
French Paradise	Type VIII.	4	55
Selected Seedling (Malling)	Type XII.	4	54
Jaune de Metz	Type IX.	4	54
Selected Seedling (Späth)	Type XV.	7	53
" Paradise "—Name unknown ..	Type VII.	4	52
Doucin Amélioré	Type V.	4	51
Crab Selected Seedling (Malling) ..	Crab F.	4	50
Nonsuch	Type VI.	4	49
Hollyleaf	Type III.	3	48
Selected Seedling (Späth)	Type X.	4	47
Holstein Doucin	Type IV.	3	45
Selected Seedling (Späth)	Type XIII.	4	42
Crab Selected Seedling (Malling) ..	Crab H.	6	8
Northern Spy		4	0

The table shows that with the exceptions of Northern Spy and Crab H. all the stocks were heavily attacked. In most cases the differences in the figures for individual stocks is greater than that between many of the means, and the figures cannot be considered as placing the Types in order of resistance. It is not considered necessary to give the individual figures in detail, but in a few

FIG. 1.

1, CRAB A.; 2, TYPE XV.; 3, NORTHERN SPY.

FIG. 2.

CRAB H.

Stocks, with different degrees of Resistance, infected under glass.

Northern Spy free; Crab H. with large but localised colonies; Type XV. and Crab A. with long stretches of wood covered with continuous colonies.

instances they will be given to show the amount of individual difference within a type that was recorded.

Type I.	69, 57, 62, 63, 65%.	Mean 63%.
Type XIII.	44, 51, 31, 44%.	Mean 42%.
Crab H.	17, 9, 4, 4, 8, 6%.	Mean 8%.

In some cases the differences were even larger, for example

Type III.	31, 48, 66%	Mean 48%.

and in some the intensity was more uniform in the four individuals of a type, for example

Type IX.	56, 55, 53, 50%	Mean 53%.

The experiment proves Crab H. to be definitely more resistant than any other Crab or " Paradise " stock tested. There is probably a significant difference between the resistance of Type XIII. and Type I. (further evidence will be adduced in support of this), but with reference to the other types no significant difference is considered to have been shown.

Photographs of some of the apples used in this test are shown in the Plate.

(iii.) *Galling of Plant.*

Measurements were made of the galls produced by fourteen types of stock. The results are found in Table III.

The galls were all measured after the stocks had been infested for one season, being measured usually after the autumn migration of sexuparæ. The diameter of the galled portion is expressed as a percentage of the normal diameter of the stem above or below.

TABLE III.

Stock	Malling designation.	Number of galls measured.	Largest gall %	Mean % and probable error.
Broad-leaved English Paradise ..	Type I.	63	200	163±1.8
Holstein Doucin	Type IV.	73	200	157±1.6
Jaune de Metz	Type IX.	74	200	153±1.7
Crab	Crab H.	111	267	152±1.6
Selected Seedling (Malling)	Type XII.	53	200	151±1.7
Nonsuch	Type VI.	31	167	146±1.7
Crab	Crab F.	42	167	145±1.7
Crab	Crab A.	44	175	141±1.0
Doucin Amélioré	Type V.	54	167	140±1.3
" Paradise "—Name unknown ..	Type VII.	36	160	140±1.2
Selected Seedling (Späth)	Type XV.	56	167	137±1.0
Doucin	Type II.	124	233	137±1.2
Crab	Crab C.	37	167	136±1.6
Selected Seedling (Späth)	Type XIII.	40	167	130±1.6
Northern Spy		0	—	—

The high position of Crab H. in the table shows that the size of gall produced does not necessarily alone give a true indication of the degree of resistance of a stock. The largest gall measured during the experiments was on Crab H. The galls on this stock grew very rapidly when once the colonies had become established, but there were generally many fewer produced on one stock than in the other types.

Again Type I. is at the top of the list and (with the exception of Northern Spy) Type XIII. is at the bottom. Taking the cumulative evidence from the three different experiments the conclusion drawn is that Type XIII. is definitely more resistant than Type I. This difference is very apparent in practical work with Woolly Aphis on these two stocks in the field.

It is not thought necessary to give any detailed figures, but the probable error in each case is added. This shows that differences of 7 per cent. to 10 per cent. may generally be considered significant; but as has been stated before differences in these figures do not necessarily indicate equal differences in resistance.

An interesting case of natural infection of some stools of Malling " Paradise " stocks was visited in North Kent in 1925. The Types of stock present were :—Type I. (Broad-leaved English Paradise), Type II. (Doucin), Type IX. (Jaune de Metz), Type XIII., Type XVI. The most heavily attacked was Type XVI.; ten stools of this type were examined and seven were recorded as " very heavy," three as " heavy." Types I. and II. were also both heavily attacked with no stools free. Types XIII. and IX. were less heavily attacked, but no stools of Type IX. were free; while out of twelve stools of Type XIII. four were free. Root attacks were found on each type. The extremely heavy attack on Type XVI. together with its high position in Table II. shows that it is very susceptible.

(iv.) *Root Infection.*

Root infection experiments were made on the following stocks in 1925 :—Types I., IV., VII., IX., XI., XII. and Northern Spy.

No method of comparing the intensity of infection on the roots with that on the top was devised. The colonies on the roots are, necessarily, smaller than those above ground; and the galling on the roots, so far as it was observed, is not comparable with that on the above ground portions. Small rootlets of 1 or 2 mm. diameter often bore galls several times larger in diameter than the rootlet. The nearest approach to such a condition on the twigs occurs in Crab H., but even here the percentage increase is not nearly so large as it may be on the rootlets. On the other hand the large roots have not been observed to produce galls as large as do stems of equal size. No detailed study of the conditions affecting root infestation was made.

In the following table the infections are classified as large or small according to the size of colony and number of roots attacked.

TABLE IV.

Root Infection.

Stock.	Malling designation.	Number Artificially infected.	Number of Infections "taken."	Large attack.	Small attack.
Broad-leaved English Paradise ..	Type I.	12	12	9	3
Holstein Doucin	Type IV.	3	3	1	2
"Paradise"—Name unknown ..	Type VII.	3	2	—	2
Jaune de Metz	Type IX.	9	9	3	6
"Paradise"—Name unknown ..	Type XI.	1	1	1	—
Selected Seedling (Malling) ..	Type XII.	9	9	6	3
Northern Spy		11	—	—	—

It will be seen that as in the test of the above ground portions Type I. was heavily attacked, and Northern Spy was found impossible to infect. No differences in resistance between the other types is claimed to have been demonstrated. None of them has a high degree of resistance.

Time did not permit any systematic work on root resistance in 1926. It was considered advisable to concentrate on infections above ground, particularly as no evidence had been obtained for believing that a stock of which the above ground portions were resistant would prove to be susceptible on the roots, or vice versa.

During 1926 the following natural infections on the roots were observed :—

Types I., V., VII., one heavy on each.

Types III., IV., VI., VII., XVI., Crab F., one slight on each.

Type XV., two slight.

2. COMMERCIAL SCION VARIETIES.

(i.) *Effect of Attack.*

Before giving results of infections on the commercial varieties selected, a small experiment planned to give an idea of the actual amount of damage that would be caused to a young tree by an unchecked infestation of Woolly Aphis, will be described.

Four maiden trees of Cox's Orange Pippin on Type I., and eight of Allington Pippin on Type II. were weighed, measured, potted and brought into the greenhouse in 1926. Two of the Cox's and four of the Allingtons were infected

with Woolly Aphis, and the infestations were allowed to increase on them unchecked, while the others were kept free by spraying (when necessary) and by treating the roots with a solution of Carbon bisulphide in water. The two Cox " controls " together weighed 9 ozs., as did the infected trees: the four Allington " controls " totalled 17 oz., as also did the infected trees. There were growing colonies on all the infected trees by the middle of May. Table V. shows the result of the experiment.

TABLE V.

Variety and Stock.	Treatment.	Increase in weight in ozs.	Total growth on March 4th, in cms.	Total new growth, measured Sept. 22nd in cms.
Cox on Type I.	Infected.	3	160	168
	Controls.	9	144	302
Allington on Type II.	Infected	6	407	277
	Controls.	16	393	466

The controls were all fairly healthy on September 22nd, whereas the infected trees were very miserable and some of them were nearly dead. The experiment shows that the difference in growth due to a four months attack of Woolly Aphis may be considerable.

(ii.) *Outdoor Test of Nineteen Varieties.*

In 1925 it was planned to test the resistance of a selection of well known scion varieties such as are used commercially. The stocks for this experiment were planted in the spring of 1925, and budded in the autumn. Most of the maidens were ready for infection in June, 1926. The stock chosen for the experiment was Nonsuch Paradise (Type VI.) because it was described by Staniland (11) as very susceptible, and was available in large numbers when the experiments began. The infections (comparably made in this experiment, on all varieties, both as regards time and method) were begun in June, and made in sleeves with a brush or piece of infected shoot. The following table gives the first year's results on the fifteen varieties tested. Only two grades of intensity of attack are recorded. A large attack means the presence of large vigorous colonies such as would usually induce definite galling. A small attack indicates the presence of healthy established colonies distinctly less in size than the others.

Besides the fifteen varieties on Type VI. the table includes three varieties (Winter Majetin, Ben Davis and Neidwetzkiana) on their own roots, and one (Zuccalmaglio Reinette) on an unknown stock. These were planted and tested

apart from the fifteen, but are included here in order to save space. Each of the four has at some time been described as immune or highly resistant.

TABLE VI.

Variety.	Number artificially Infected.	Large attack.	Small attack.
Bramley	8	2	3
Lane's Prince Albert	6	4	1
Worcester	7	3	4
Newton	7	2	3
James Grieve	5	4	0
Rival	5	4	1
Beauty of Bath	5	5	0
Grenadier	8	3	4
Gladstone	5	1	3
Early Victoria	5	4	1
Annie Elizabeth	7	0	6
Derby	7	1	6
Bismark	4	2	2
Norfolk Beauty	5	3	0
Duchess of Oldenburg	6	1	5
Winter Majetin	7	0	0
Neidwetzkiana	2	0	0
Ben Davis	8	1	3
Zuccalmaglio Reinette	1	1	0

These preliminary results show that no high degree of resistance is to be expected among the commercial varieties tested. Of the fifteen, Beauty of Bath is probably the most susceptible. On Winter Majetin it has not been possible to induce permanent colonies, although insects will live on it for several weeks, as on Northern Spy, but possibly somewhat more easily. It may be considered that the present tests have added more confirmation to the general belief that it is immune. The two plants of Neidwetzkiana never became infected in two years' attempts, but no definite statement will be made on such small numbers. Ben Davis was definitely more difficult to infect than some other varieties, but good colonies, inducing definite galling, were established on it. The one tree of Zuccalmaglio Reinette was kept under glass in 1925 and though it took longer to infect than the other varieties present, a very heavy attack developed on it inducing much galling.

3. THE INTERACTION OF STOCK AND SCION.

This experiment was planned to attempt to discover whether the resistance of the stock to Woolly Aphis attack has any influence on the resistance of the scion worked on it, and vice versa.

The susceptible varieties chosen were Cox's Orange Pippin, Allington Pippin and Nonsuch Paradise (Type VI.); the varieties chosen, reputed to be

resistant, were Irish Peach, Transparent de Croncels, and Northern Spy. Each of these six varieties was worked on ten Northern Spy stocks and ten Nonsuch Paradise stocks. As in the varietal test these trees were worked 3 or 4 inches higher than in commercial practice. The infections were made from June till October and were comparable on each variety both as regards time and method. All the infections were bagged ; until August they were made on all trees, with insects from shoots kept a few days in pill-boxes ; afterwards a piece of infected shoot was placed in each bag, as formerly described.

The following are the first year's results described in the same manner as in the commercial variety experiment.

TABLE VII.

Scion.	Stock.	Number artificially infected.	Large attack.	Small attack.
Cox's Orange Pippin	Spy	5	4	1
	VI.	4	2	2
Allington Pippin	Spy	4	1	2
	VI.	10	2	8
Nonsuch Paradise (Type VI.) ..	Spy	6	3	1
	VI.	5	2	2
Irish Peach	Spy	4	0	3
	VI.	4	0	3
Transparent de Croncels	Spy	4	1	2
	VI.	8	2	5
Northern Spy	Spy	3	0	0
	VI.	7	0	0

The table gives the infections on the scions but makes no mention of the attacks on the stocks. Type VI. was frequently attacked on the roots and on that portion of the stock above ground. Northern Spy was never attacked. No differences in the attacks on Type VI. when different varieties were worked on it, were recorded. The high budding did not have the desired effect of causing the scions to become more readily infected from the attacked stocks.

The table shows that, in this preliminary test, no consistent differences occurred in the number attacked or the intensity of attack on varieties according to whether they were worked on Northern Spy or Type VI. On these first

results it is not possible to state definitely that the resistance of the stock does not influence the resistance of the variety worked on it, to a small degree, but the results show that it does not have a noticeably large effect. This is indeed what was expected from knowledge of commercial practice abroad where resistant stocks are used ; but further experimenting on this line may help to throw light on the nature of resistance.

The fact that a susceptible stock may be a constant source of infection for the scion (and thus cause it to be generally more heavily attacked than if it were on a resistant stock) is not directly pertinent to the question being considered.

4. TRANSMISSION OF IMMUNITY TO NEW SEEDLINGS.

The seedlings bred by Mr. M. B. Crane for the purpose of discovering whether the character of immunity could be transmitted, and if so of combining with it desirable features of some of the Malling selections of "Paradise" stocks, that were tested by the writer for their degrees of resistance to Woolly Aphis were the following :—

(i.) Thirty-six seedlings of parentage Northern Spy × Doucin (Type II.). Of these (a) nineteen had been propagated at East Malling, and a limited number of layered shoots of each was available.

(b) Seventeen were seedling trees four or five years old.

(ii.) Five seedling trees of parentage Northern Spy × Jaune de Metz (Type IX.)

(iii.) Seven seedling trees of parentage Lane's Prince Albert × Northern Spy.

(iv.) Four seedling trees of parentage Northern Spy selfed.

These four groups will be dealt with separately.

(i.) *a. Resistance of Layered Shoots from Nineteen Seedlings (N. Spy × Doucin).*

Five stocks from each seedling (with the exception of four) were planted in the open in 1925. Infections were begun on them in June. In many cases heavy attacks were recorded by August 11th. Owing to the less efficient technical methods employed for making infections early in 1925, than were devised later, it was not always possible to infect right through on the same day, so some stocks had more inducement to become infected by August 11th than others. But by August 4th most of the stocks had been artificially infected three or four times. Other infections were made after this date.

A thorough examination of each individual was made on October 28th, 1925, when attacks were very general and heavy on the experimental stocks. The method previously described of allotting figures 1 to 5 according to estimated intensity of attack was employed. Except in the following cases, 765 (two), 766, 774, 776 (four each), five stocks from each seedling were artificially infected.

The results obtained are tabulated.

TABLE VIII.

Layers from Seedlings N. Spy × Doucin.	Number on which Infections existed on Oct. 28th.	Estimated individual intensity of attack on Oct. 28th.	Average estimated intensity.
759	—		
760	5	1, 3, 3, 5, 3	3.0
762	5	2, 2, 3, 4, 3	2.8
764	—		
765	—		
766	—		
770	—		
772	5	2, 2, 1, 3, 3	2.2
773	1	1	0.2
774	2	4, 3	1.8
776	—		
778	—		
780	5	2, 2, 3, 5, 3	3.0
782	—		
783	—		
786	—		
787	1	1	0.2
790	5	2, 2, 3, 2, 3	2.4
792	1	1	0.2

The results tabulated showed that layers from six of the seedlings were susceptible and from three (773, 787, 792) were uncertain. Of the remaining ten which did not become infected nothing could be deduced from the infections described above.

In 1926 other layered shoots from the same seedlings were planted. Infections were being made continuously throughout the summer in other experiments, and no time was found to infect this series till September, but they were intentionally allowed to become infected from a nearby experiment. The following layers became naturally infected more or less heavily; 762, 765, 772, 774, 776, 780, 787, 790. It will be seen that several of these are from seedlings of which layers had been proved susceptible in 1925.

For the rest of the year work with these stocks was confined to attempts to infect those on which colonies had not been recorded.

The infections were made both on the older material (planted in 1925) and on that planted in 1926. The stocks were wounded in each case, and into the sleeve surrounding the wounds was placed a piece of shoot on which were usually between 500 and 2,000 insects. The sleeves were left on from two to four weeks. It should be stated that infections made in a similar manner and even without wounding, during the same month, in other experiments were very successful. It is justifiable to assume therefore that the lack of success on these stocks was due to their high degrees of resistance.

Table IX. gives the results of this series of infections.

TABLE IX.

Layers from Seedlings N. Spy × Doucin	Number artificially infected.	Number of infections "taken."	Condition on October 18th.
759	4	—	
764	4	—	
766	4	—	
770	4	—	
773	4	—	
778	4	2, slight.	Some small groups of insects on one ; other free.
782	4	—	
783	4	2, slight.	Some insects still alive on one ; other free.
786	4	1, slight.	Small groups of insects still alive.
792	4	3 ; 1 slight. 2 fair.	Quite good small colonies on three individuals.

The way in which insects lived for several weeks in cracks, was almost exactly similar to that which occurred in " control " infections made on Northern Spy at the same time. The behaviour of the infections (for example as regards number of insects living in cracks and the time they remained on the plants) was in all respects comparable on Northern Spy and on some of these hybrid stocks. Among the ten seedlings in Table IX. are doubtless some with a degree of resistance equal to that of Northern Spy, but the writer would not be satisfied in definitely stating them to be immune without having given them one year's intensive infection under glass.

The following is a summary of the present classification of these nineteen seedlings.

Very susceptible or Susceptible—

760, 762, 765, 772, 774, 776, 780, 787, 790, 792.

Resistant—

759, 764, 766, 770, 773, 778, 782, 783, 786.

The resistant seedlings have a range of vigour varying from small to strong growing, which encourages the hope that it may be possible to produce a series of immune layered stocks comparable with the existing " Paradise " stocks, all of which have been shown to be susceptible.

(i.) *b. Resistance of Seventeen Seedling Trees (N. Spy × Doucin).*

Thirteen of these trees were planted in the open in 1925, and four were kept under glass. Infections were begun on those in the open on June 15th, and though they proved difficult to infect, by August 11th attacks existed on nine of them,

Numbers 761, 763, 767, 771, 775, 777, 784, 785, 791. The four trees on which no infections could be induced during the year were 768, 779, 781, 788.

The four trees (758, 769, 789, 793) kept under glass in 1925 were first infected with one aphid each on June 13th. In the case of 758 four infections were made before a colony was recorded on July 16th. With 769 five infections were made and a colony was recorded on July 21st. The other two trees were quite free on July 28th; six infections are recorded on each up to that date. The colonies on 758 and 769 increased very rapidly, and by the end of the year a very heavy infection was present on each. The attack was so heavy that the trees only made poor efforts at growth in 1926 and, somewhat unexpectedly, died. The other trees (789, 793) resisted numerous efforts to infect them throughout 1925 and were considered to have a degree of resistance equal to that of their Spy parent, that is to be immune. These trees are now being propagated, for the production of stocks for further testing from the entomological and pomological points of view.

Root infections were made on these four trees, with positive results on the susceptibles and negative on the immunes.

Six of the trees tested in the open in 1925 (the four that could not be infected and 775, 771) were potted early in 1926 and brought into the greenhouse for intensive infection.

Infections were first made (using between thirty and fifty insects on each) on May 17th. Colonies quickly developed on 771, 775, but constant infections during the summer could not induce attacks (with the exception of some small colonies on 768) on the other four. The condition of the six trees on August 8th was as follows :—

779, abortive attempts to settle down, similar to those on Northern Spy.

781, abortive attempts, with the exception of one tiny colony in a crack, which however did die out later.

768, new wood quite free. A few small colonies in burr-knots.

788, abortive attempts only.

775, many large colonies on new wood and several on old.

771, very heavy attack. Many stretches of new wood and some of the old completely surrounded by insects.

After this date great efforts were made to induce colonies on the four resistant trees, by wounding and sleeving large numbers of insects on them. A final examination on September 27th showed that 779, 781, 788, had resisted these efforts. 768 had fair colonies on many of the burr-knots although the rest of the tree, including the new wood on which the infections had been made, was free.

The original seventeen seedling trees may now be classified thus :—

Very susceptible or Susceptible—

771, 775, 758, 769, 761, 763, 767, 777, 784, 785, 791.

Resistant—

768.

Immune—

789, 793, 779, 781, 788.

It should be stated here that Mr. Staniland also tested these seventeen seedling trees and he also found the above five immunes and one resistant to be either resistant or immune. This adds support to the classification given above.

(ii.) *Resistance of Five Seedlings (N. Spy × Jaune de Metz).*

These were tested under glass in 1926. A large number of infections were made on these trees during the summer. The first established colony recorded was on tree 1 on August 18th.

Their conditions on September 6th and October 19th were as follows :—

	September 6th.	October 19th.
1.	Some good colonies on new wood.	Heavy attack on old and new wood.
2.	Some slight colonies on new wood.	Slight colonies on new wood—not increased.
3.	Free.	Free.
4.	Free.	Slight colonies on old wood.
5.	Slight colonies on old wood.	Many colonies on old wood and some growing ones on new.

Between September 6th and October 19th infections were made on all except number 1 by sleeving large numbers of insects on them. With the exception of number 1 all the trees were more difficult to infect than "susceptibles" in other groups. The present classification of these trees must be :—

Susceptible—1, 5. Resistant—2, 3, 4.

(iii.) *Resistance of Seven Seedlings (Lane's Prince Albert × N. Spy).*

These were tested under glass in 1926. Infections were first made on them on May 25th, and several other infections were made both in June and July. Their conditions on August 18th and September 28th were as follows :—

	August 18th.	September 28th.
1.	Attack heavy on new wood. Spurs and cracks in old wood infected.	Attack heavy. Large and often continuous colonies on old and new wood.
2.	Many fair colonies on new wood. Attempts to settle down on old.	Some fair colonies on old and new wood.
3.	Many fair colonies on old and new wood.	Some fair colonies on old and new wood.
4.	Several very small colonies on new wood.	Free.
5.	Very small colony at base and attempts on new wood.	Number of fair colonies and some galling Fair infection on new wood.
6.	Two tiny colonies.	Two tiny colonies.
7.	Heavy attack. New wood with numerous large colonies, old wood also with colonies.	Very heavy attack. Long continuous colonies on old and new wood.

In several of the above cases the attack was less heavy on September 28th than on August 18th. This was usually due to the fact that a large number of winged sexuparæ had been produced and these had left the trees.

The present classification of these trees is :—

Very susceptible and Susceptible—
7, 1,—5, 2, 3.

Resistant—
6, 4.

(iv.) *Resistance of Four Seedlings* (*N. Spy selfed*).

These were tested under glass in 1926. The first infections were made on them on May 21st. Their conditions on August 18th were :—

1. Free.

2. Small shoot at base heavily attacked. Several good colonies on new wood. (Eleven colonies in fourteen consecutive buds on one shoot.)

3. A few fair colonies.

4. Good attack with large colonies on main shoot.

Numbers 2, 3 and 4 were all fair sized three-year old trees, and on each it was estimated on September 27th that more than 100 inches of growth were

attacked. They had, however, made plenty of good sturdy new growth. Number 1 was very small indeed and made little growth during the year. This shows clearly what was mentioned previously, that the resistance cannot be ascertained by a measure of the growth of the plant, unless the " normal " growth in conditions in all respects similar to that made when attacked, is known. This can never be possible in the case of single seedlings but might prove feasible with large numbers of vegetatively raised plants.

The classification of these Northern Spy selfed seedlings is :—

Very susceptible—2, 3, 4.

Immune (or Highly Resistant)—1.

Elsewhere no plant has been described as "immune" that has only been tested during one year, or that has been tested two years in the open without having also been tested under glass, so a qualification is made (in brackets) in the above case. Very strong efforts were made to infect the above plant, and in addition insects were crawling about it from nearby infections during most of the summer. It has therefore completely withstood the most stringent tests possible to give it.

The results of this test, together with the others in which Northern Spy was a parent, indicate that whatever determines immunity probably segregates in a Mendelian manner. The fact that Northern Spy selfed gives both immunes and susceptibles renders it probable that immunity is dominant, but at the present stage of the investigations the evidence is much too slight for any definite genetic conclusions to be drawn.

No work has been done during the present investigations on the possible causes of differences in resistance, or to discover what is the factor (or factors) that is capable of transmission to the offspring, and possession of which makes a plant immune. French (3) records the results of ash analyses of a resistant and a susceptible apple, differences in which cannot alone be considered to have any significance. Staniland (12) examined the sclerenchyma in the stems of types of apple stocks and concluded that though the percentage of sclerenchyma might be connected with resistance it did not explain complete immunity. Differences in the chemical constitution and hydrogen-ion concentration of the cell sap have not been studied in relation to the resistance of apple to the Woolly Aphis in this country. Monzen (17), from an experiment made in Japan, concluded " that the susceptible varieties of apple show the greater Ph. values in their juices than the immune varieties." The present writer suggests that this is a very suitable line for further chemical and chemico-physical investigations on this question, because the character of immunity of certain varieties of apple is so definite and because of what has been shown regarding its inheritance.

SUMMARY.

1. References are made to papers dealing either wholly or in part with the resistance of varieties of Apple to the Woolly Aphis (*Eriosoma lanigerum* Hausm.).

2. The technique used for artificial infection of apple with this insect is described. A short account is also given of troubles caused by certain apple pests, and the methods used against them.

3. The question of resistance is discussed, and methods used in the attempt to determine the degrees of resistance of varieties of apple root stocks are described and examined.

4. A description of the results of heavy artificial infections of Northern Spy is given, and mention is made of its use as "control" particularly when examining highly resistant plants.

5. Tests of commercial root stocks showed one out of eighteen varieties of stock tested, to be more resistant than all the others, but no further definite grouping according to degrees of resistance was found possible.

6. The preliminary results from artificial infections of fifteen commercial scion varieties show that none of them is immune or highly resistant. Four other varieties reputed to be resistant were tested.

7. First infections on maiden trees prepared for the purpose of testing whether there is interaction between stock and scion with respect to Woolly Aphis resistance, show no definite results in favour of belief in such interaction, but rather indicate the probability that if there is influence in this respect it is slight.

8. Tests of seedlings derived from crossing Northern Spy with susceptible varieties have shown that the factor or factors which determine immunity are inherited. They also indicate that Northern Spy is heterozygous in respect of this character.

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REVERSION IN BLACK CURRANTS:

A STUDY OF THE CHROMOSOME COMPLEMENT.

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The circumstances of "reversion" in the black currant (*Ribes nigrum*) recall in many ways a genetic mutation of the kind that has been found in seedlings in other species to be associated with chromosome abnormalities. The loss of fertility, the alteration in the proportions of the leaf and floral parts, the reduction of the normal pubescence and increased pigmentation of flower buds, constitute a group of changes not altogether unlike those found, in *Datura* by Blakeslee, in *Matthiola* by Frost, and in *Avena* by Huskins, associated with the loss or gain of a single chromosome.

It was therefore thought desirable to substantiate or eliminate this possibility by examining the chromosome complements in somatic cell divisions from normal and reverted bushes. For this purpose cuttings of specially selected individuals were obtained from East Malling and root-tips of both types were taken for study.

These were fixed in a modified Flemming solution and stained with gentian violet.

The illustrations (x4100) show somatic metaphases, A in a root of a normal plant and B in one of a reverted plant. The chromosome numbers are the same ($2n = 16$) and so far as

can be determined, where the bodies themselves are so small—the largest is not more than 2.5μ in length—the complements are identical and the same forms occur in both types. Reversion is therefore not due to loss or gain of a whole chromosome.

There is one pair of long chromosomes with median constrictions, one a little shorter, with sub-median constrictions, and one with sub-terminal constrictions. There are four pairs of medium length, two with median constrictions, one of these having also terminal satellites and two with sub-terminal constrictions. Lastly there is one small pair with submedian constrictions.

This complement is evidently comparable with that of other species of *Ribes*; for example, *R. grossularia* and *R. Oxyacanthoides* have sixteen chromosomes. C shows a somatic metaphase from a hæmatoxylin preparation of a root-tip of the gooseberry variety, "Whitesmith." The chromosomes with satellites are again present and the other forms are mostly recognisable.

It should be particularly noticed that the pair with satellites occurs in both normal and reverted plants, so that the possibility, not to be forgotten, of the phenomenon being due to the loss of a satellite such as has actually been observed in *Crepis* by Navashin, may also be ruled out.

Loss of any fraction of a chromosome other than a satellite, or "point mutation", can hardly be seriously considered as a cause of so constantly recurring a phenomenon. Although, therefore, the possibility of genetic explanation cannot be entirely dismissed I am inclined to regard it as remote.

For the material used in these observations I am indebted to Mr. R. G. Hatton, Director of the East Malling Research Station.

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LEAF SCORCH ON FRUIT TREES.

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PART I.—INTRODUCTION.

In the Annual Report of the Long Ashton Research Station for 1921 (2) an extensive account was given of the investigations carried out on " Leaf Scorch of Fruit Trees " at the Station up to that time.

In discussing the results obtained in these investigations it was pointed out that in every case examined the water relations of the leaf tissues were apparently involved. Leaf scorch appeared to develop under certain conditions conducive to inadequate water supply within the foliage.

In considering water relations in the leaves, the desirability of considering not only loss of water from the leaves by transpiration but available water supply to the leaves by means of root action was emphasised. It was shown that whilst under certain conditions of water shortage wilting results, apparently under others leaf scorch is produced.

Evidence from pot experiments with apple trees indicated that deficiency of potassium in the nutrient medium was favourable to the development of scorching and cases were cited in which scorch had disappeared from trees growing under field conditions following the application of potassic manures.

Field observations were reported in which leaf scorch had notably decreased following the " grassing down " of affected trees.

In the soil studies discussed it was shown that where scorching occurred the soil texture was usually very open and likely to cause summer drought whilst in a few cases it was of a peculiar compacted character which was very probably unfavourable to efficient root development.

Cases were also mentioned which indicated that root stock action was of importance in the case of apple trees.

Since the publication of the above paper, work has been continued along certain lines with a view to elucidating certain problems which arose and to elaborating evidence along certain lines which appeared of importance to a wider knowledge of the problem. These studies have been wholly concerned with problems of physiology and nutrition. Certain of the physiological results have been reported previously in two papers by Summers (12) and Mann (5).

It is the purpose of the present paper to record the results of the nutritional investigations carried out by the writer.

Summers (*loc. cit.*) in his paper, discussed certain transpiration phenomena in relation to scorching and reported results obtained in experiments on the interference with the water supply to the leaf. He concluded from these latter that the scorched leaf results from a rapid breakdown of the water supply to the leaf under conditions of a severe and sudden evaporation pull on the water of the leaf. In the case of wilting the conditions producing drying out are more gradual.

He also examined the production of the characteristic marginal browning which occurs on scorched leaves and concluded that it is in all probability due to the action of oxidising enzymes upon the chromogens produced during the drying out of the leaves. This last point is one which merits special attention. In attempting to controvert the theory that leaf scorch is the result of a drying out process, the argument has frequently been advanced that scorching cannot be the result of such a process since it often makes its appearance during a wet period of weather whereas no signs of it had been observed during a previous period of hot dry weather. The observations of Summers serve to clarify this point. The drying out process takes place during the hot dry weather and results in an incipient stage which often passes unnoticed. When the dry conditions subsequently give way to moist ones oxidase action commences and the brown stage results.

Mann (*loc. cit.*) examined some effects of potassium and calcium starvation on the foliage of apple trees and gooseberry bushes in sand cultures and obtained results which throw light on the action of potassium in controlling leaf scorch.

Working with apple trees he showed that deficiency of potassium results in decrease in leaf size whereas deficiency in calcium results in increase in leaf size.

Using gooseberry leaves detached from the shoots, the water content of leaves from potassium deficient bushes was found to be lower and from calcium deficient bushes higher than that of leaves from bushes fed with a complete nutrient solution.

The rates of water loss from similar sets of detached leaves from these bushes were compared at two different temperatures, 18° C. and 25° C., and it was found that, especially at the higher temperature, the potassium deficient leaves lost water much more rapidly than those from the complete nutrient bushes, whilst the rate of loss from the calcium deficient leaves was slower than from those from the latter bushes.

Finally, the transpiration rates of apple leaves from trees of the series "potassium deficient," "complete nutrient," and "calcium deficient" were compared under conditions of low illumination and of high illumination. Under conditions of low illumination the transpiration rate of the potassium deficient foliage was lower than those of the "complete nutrient" and "calcium deficient" series, which rates were similar, whereas under conditions of bright illumination the transpiration rate of the potassium deficient leaves rose above those of the other two series. Under these latter conditions the calcium deficient leaves showed a lower rate of transpiration than did those from the "complete nutrient" trees.

Mann's results indicate that the leaves of "potassium deficient" trees have a relatively low water content and that under conditions favourable to rapid transpiration such leaves possess relatively poor resistance to water loss.

Before passing to the description of the results of the present investigation it will be convenient to refer to results obtained by Hatton and Grubb (3) at East Malling Research Station.

These workers recorded the incidence of scorch on a block of apple trees consisting of several varieties on various root stocks and examined the data in relation to root stock types, varieties, pruning, blossoming, cropping and manuring. They concluded that root stocks exercised very decided effects on the susceptibility to leaf scorch of the scion varieties worked on them. Trees on Malling Type V were extremely susceptible to scorching, those on Malling Types II, VII, were also distinctly susceptible whilst those on certain other stocks were relatively resistant. In this paper a list of varieties in order of susceptibility to scorch as determined on the Malling plots is presented. Cropping appeared to promote leaf scorch development whilst pruning appeared to ameliorate the condition. It is pointed out that the pruning effect may be largely or wholly due to decreased cropping which resulted from this treatment. Manuring with dung and artificials reduced the amount of scorch but it was not clear how the manures had effected the result.

Hatton and Grubb are of opinion that the fundamental problems of leaf scorch are nutritional.

The investigations reported in the present paper fall naturally into three distinct groups and accordingly are dealt with in three sections as under :

1. Pot experiments with trees and bushes in sand culture.
2. Soil investigations.
3. The control of leaf scorch in the field.

PART II.—POT EXPERIMENTS WITH TREES AND BUSHES IN SAND CULTURE.

1. Experiments on Potash Deficiency.

(*a*) *Experiments with nutrient solutions.*

In the paper on leaf scorch, published in the Annual Report of the Long Ashton Station, 1921, and mentioned above (2), results are presented of pot experiments carried out during that season in which apple trees were grown in sand and fed with nutrient solutions as follows: complete nutrient solution; nitrogen omitted; potassium omitted; phosphorus omitted; calcium omitted; magnesium omitted; water only. In that experiment the trees receiving the treatment "potassium omitted" suffered more severely from leaf scorch than did those in any other series, which appeared to indicate that the potassium contained in the other solutions exercised a controlling action over the development of leaf scorch.

In the following year similar experiments were commenced with gooseberry and black currant bushes and in 1923 a further series was started with raspberry plants. These experiments were subsequently continued over three or four seasons and careful records were made on the occurrence of leaf scorch in relation to the nutritional treatments. The complete results have been reported previously (17). In all cases in each season leaf scorch was developed only in the cases of plants receiving the treatment "potassium omitted" and it has been clear from the results that leaf scorch is a characteristic symptom exhibited by the leaves of these plants when grown under conditions of potassium starvation.

The other treatments effected equally characteristic symptoms on the foliage which were quite distinct from leaf scorch.

By the end of the growing season of 1922 it became evident that the apple trees which received the treatment "nitrogen omitted" were less susceptible to leaf scorch than those receiving a complete nutrient solution and hence in 1923 an experiment was carried out on apple trees in sand culture to examine the effect of varying the ratio of $\frac{\text{nitrogen}}{\text{potassium}}$ on the production of leaf scorch. The results of this experiment have also been published (15, 17) and need not be fully recorded in this paper. It is sufficient to state that it was found possible to eliminate leaf scorch from the series receiving the original complete nutrient solution by increasing the amount of potassium in the nutrient solution and keeping the amount of nitrogen constant. Further, when the amount of potassium remained unchanged but the amount of nitrogen was reduced by approximately one half, scorching was also greatly mitigated. Since the results of this experiment came to hand the complete nutrient solution used in

all subsequent experiments has had a narrower ratio for $\frac{\text{nitrogen}}{\text{potassium}}$ than the original one and with its use scorching has never appeared on any trees or bushes grown by us.

From these experiments it seems clear that nitrogenous feeding is conducive to leaf scorch development, whilst potassic feeding tends to suppress its development.

(*b*) *Experiments on the control of leaf scorch by spraying with sulphate of potash.*

The action of potassium in controlling leaf scorch has been examined in another way.

For some time the writer has been interested in the problem of chlorosis of fruit trees and in the course of investigations on that subject has attempted to control chlorosis by spraying the chlorotic foliage with a solution of sulphate of iron. It has been evident in these experiments that the iron of the salt was able to enter the leaf tissues when so applied.

Further, it has been shown by Mann and the writer (6) that it is relatively easy to wash potassium salts out of the leaves of apple trees.

In view of these results it occurred to the writer that it should be possible to supply at least a certain amount of potassium to fruit trees by means of spraying the foliage with a solution of a potassium salt at an appropriate strength and it was decided, accordingly, to examine this possibility.

Before commencing a critical experiment on any considerable scale, a small preliminary experiment was carried out to test certain details of procedure.

Preliminary Experiment, 1925.—Four gooseberry bushes, variety King of Trumps, were selected for treatment. They had been growing in sand in pots since 1922 and had received the nutrient treatment, "potassium omitted," during the whole of that period. Each year the bushes had suffered markedly from leaf scorch and had exhibited every appearance of acute potassium starvation.

Each pot was fitted with a tarpaulin cover of the usual pattern used in these experiments to prevent access of rain to the pots. For the experiments, in addition to this cover, each pot was fitted with a large disc of waxed cardboard over the top of the tarpaulin. Each disc had a hole in the centre which fitted round the stem of the plant and the stem was fitted into this by cutting a slit from the edge of the disc to the hole and slipping the stem into position along the slit. The slit was subsequently closed by a strip of adhesive tape. In addition, each plant had a piece of cotton wool fitted round the stem at a point above the cardboard. The object of these fittings was to preclude the possibility of any of the spray reaching the sand in the pot.

During the course of the experiment all four plants were kept under a glass roofed structure with open sides in such a position that they were protected from rain throughout the period.

The bushes were subjected to the following treatments :—

a. All received the nutrient from which potassium was omitted as previously.

*b.*1. The foliage of two bushes was sprayed at frequent intervals throughout the season with a 1 per cent. solution of sulphate of potash.

From early April to early July the spraying was carried out weekly ; from the latter time to October the spraying was given fortnightly.

2. The foliage of one bush was sprayed with water on all occasions that the bushes in 1. received sulphate of potash.

3. The foliage of one bush was sprayed with a 1 per cent. solution of sulphate of potash as in 1. from May 21st at which time the leaves were showing marked scorch, the condition having been first noted on the bush on April 24th.

Treatment *b.*3. was included to see whether improvement could be effected after scorching had actually occurred.

Observations on the foliage under the three treatments from July 18th are given below.

TABLE I.

Observations on Leaf Scorch.

Date.	Two Bushes sprayed with K_2SO_4 from early April.	Water Sprayed Bush.	Single Bush Sprayed with K_2SO_4 after scorching.
July 18th.	A few leaves showed slight scorching.	Scorch very severe. Many leaves completely dried out.	Scorch severe.
Aug. 2nd.	Do.	Much defoliation following scorch. Leaves retained practically dried out.	Do.
Aug. 26th.	Foliage generally an excellent green colour. A few leaves show slight scorching.	Do.	All foliage severely scorched.
Sept. 18th.	Do.	Foliage retained all shrivelled up.	Do.
Oct. 3rd.	Do.	Do.	Do.

PLATE I.

Showing typical foliage on shoot of gooseberry bush sprayed with 1 per cent. solution of sulphate of potash—Oct. 16th, 1926.

PLATE II.

Showing typical foliage on shoot of gooseberry bush sprayed with water—Oct. 16th, 1926.

Experiment, 1926.—Eleven gooseberry bushes from the same series as those used in 1925 were selected for a larger scale experiment in 1926. Six bushes were chosen for spraying treatment with a 1 per cent. solution of potassium sulphate, the remaining five being reserved for spraying with water.

The details of procedure followed in 1925 were adhered to in this experiment.

The first spraying treatments were given on April 7th on which date the foliage on all plants was in excellent condition and entirely free from leaf scorch. In this experiment all six bushes selected for treatment with the potassium spray were sprayed from the above date, no bush being reserved for treatment after scorching.

Spraying was carried out at weekly intervals from April 7th to the end of June and at fortnightly intervals from the latter date until October 3rd.

Photographs were taken of typical shoots from a sprayed bush and an unsprayed bush on October 16th and these are shown in Plates I. and II.

TABLE II.

Observations on Growth and Leaf Scorch.

Date.	K_2SO_4 Sprayed.	Water Sprayed.
April 26th	Foliage excellent.	Foliage excellent.
May 8th May 16th	Foliage excellent. Leaves larger than in water series. Foliage and shoot growth excellent.	Leaves dull green and exhibit curling towards under surface. Slight scorch showing. All bushes have smaller leaves and shorter shoots than K_2SO_4 series.
June 6th	Do.	Leaves relatively small; dull green colour; show curling towards under surface. Scorch fairly severe.
June 28th	Do. A trace of scorching on a few of older leaves.	Scorch severe all plants.
July 11th	Do.	Do.
Aug. 8th	Do. A few scorched leaves on three bushes.	Practically every leaf badly scorched.
Sept. 24th	Do.	All foliage severely scorched and in crippled condition.
Oct. 16th	Do.	Much defoliation and much foliage completely dried out.

From these two experiments it seems evident that the gooseberry bushes used, suffering from acute potassium starvation, were able to take in sufficient

of the element through their leaves from a 1 per cent. solution of potassium sulphate to prevent the development of leaf scorch.

It is concluded that the effective radical in the experiments is the potash radical since it has been found in other experiments that deficiency of the sulphate radical is not characterised by leaf scorch.

2. Experiments on the Production of Leaf Scorch by Water-logging and non-leaching.

In carrying out investigations on the occurrence of leaf scorch in the field, it has been frequently observed that scorch areas coincide with soil areas of poor drainage which are susceptible to waterlogging during wet periods.

In such cases there are usually certain periods during each year when the soil conditions are favourable to growth and others when the root systems become waterlogged. These conditions tend to produce a tree which functions normally during favourable periods and produces healthy growth of shoot and root. If after such a period the soil becomes waterlogged the root activity is decreased and root killing may take place. Under these conditions the root will become unable to support the top adequately and it is reasonable to expect that the tree will attempt to reduce its leaf surface in such cases. One method by which it may accomplish this is by " scorching."

An attempt has been made to simulate these conditions in pot culture to see whether leaf scorch would result.

Experiments on the waterlogging of gooseberry bushes.

(a) 1925 *Experiment.*—Three gooseberry bushes, variety King of Trumps, which had been growing in sand in pots and receiving a complete nutrient solution since spring, 1922, were selected for waterlogging treatment in the spring of 1925. In previous seasons these bushes had behaved normally, had borne excellent foliage and fruit and had shown no signs of leaf scorch at any time. Ten plants from the same series were used as controls.

The nutrient treatment previously given was continued to all bushes throughout the duration of the experiment.

The three selected bushes were grown without differential treatment until June 14th in order that they might each develop a set of healthy fully expanded leaves. On this date the pots containing them were placed in bowls, about 5 in. deep filled with rain water. The bushes were grown on in this condition for the remainder of the season, nutrients being supplied to them in equal quantity as to the controls. The controls received no special treatment of any sort.

The observations recorded on the foliage are given in Table III. (See also Plate III.)

PLATE III.

Showing defoliation of gooseberry bush following leaf scorch from waterlogging. Waterlogged bush on left; bush not waterlogged on right.

TABLE III.

Observations on Waterlogging Treatment.

Date.	Controls.	Waterlogged Bushes.
June 30th	Foliage normal green.	Leaves showed pale margins.
July 12th	Do.	A little marginal scorch present.
July 17th	Do.	Leaves pale yellow margins. Marginal scorch severe.
Aug. 2nd	Do.	Scorch severe and much defoliation.
Aug. 26th	Do.	Two plants practically defoliated. Third severe scorch and 50 per cent. defoliated.
Sept. 6th	Do.	Do. Third plant showed some red and yellow tints during defoliation.

Note.—Prior to scorching no purple tints were developed on the leaves of the waterlogged bushes such as have been strongly in evidence on gooseberry bushes in similar experiments in which leaf scorch has resulted from the treatment "potassium omitted."

(b) 1926 *Experiment.*—The above experiment was repeated in 1926 using eight bushes of the control series of 1925, four being subjected to waterlogging and four remaining untreated as controls.

TABLE IV.

Observations on Waterlogging Treatment.

Date.	Controls.	Waterlogged Bushes.
June 15th	Foliage healthy green.	Foliage healthy green.
July 3rd	Do. but a little red tinting.	Fair amount of purpling.
July 11th	Do.	Leaves showed purple and red tints and were in many cases pale green.
July 19th	Do.	Leaves pale with reddish tints.
Aug. 2nd	Do.	Do.
Sept. 24th	Do. but red and yellow tints stronger.	One plant defoliated. One plant pale edged leaves and showed leaf scorch. Two plants reddish tints of "total starvation" type.
Oct. 26th	Bushes 50 per cent. defoliated. All show reddish yellow tints.	One plant defoliated. Three plants 50 per cent. defoliated and showed strong "starvation" symptoms.

The procedure was as in 1925, waterlogging being commenced on June 6th on which date the foliage on all bushes was vigorous and a healthy green colour. The results are given in Table IV.

The results obtained in the two experiments were not identical. Typical marginal leaf scorch resulted from waterlogging on all the waterlogged plants in 1925, but in 1926 only one treated plant exhibited scorching, the others showing tints resembling those associated with "total starvation" treatment. This latter condition has also been noted on badly drained areas in the field.

The experiments show that marginal leaf scorch can result from waterlogging treatment.

(c) *Experiments on non-leaching of the nutrient medium.*

In carrying out deficiency experiments in sand culture with gooseberry and black currant bushes and strawberry plants it has been part of the normal procedure to leach through the sand in the pots periodically—generally fortnightly—throughout each growing season with a view to preventing the accumulation of unabsorbed salts from the nutrient solutions employed. In each series, however, certain pots have been set aside which have not received the leaching treatment and in which excess salts have been allowed to remain. This non-leaching treatment has proved very deleterious in the case of strawberry plants and in several experiments has caused the death of every plant under each nutrient treatment in less than two seasons. Gooseberry and black currant bushes on the other hand have made larger growth under non-leaching treatment than have the corresponding bushes receiving leaching treatment.

In every case where non-leaching treatment has been given it has been noted that the tints which ordinarily develop towards the period of defoliation as the result of the various nutrient treatments have been either wholly or partly suppressed and that leaf scorch has been more or less strongly developed in their place. Scorching was not generally pronounced from this treatment in nitrogen deficient series and effects were negligible where "water only" treatment was given.

These conditions are probably simulated in cases where impervious subsoils occur, numerous examples of which are furnished in the section on soils.

3. Experiments on the Susceptibility to Leaf Scorch of Apple Stocks and Varieties.

As it had been shown by Hatton and Grubb (*loc. cit.*) in the field plots at East Malling that it was possible to place the varieties growing on the plots in a definite order of susceptibility to leaf scorch and that varieties on certain root

stocks were more prone to scorch than on others, it was resolved to test whether the orders of susceptibility of varieties and stocks could be ascertained by pot culture methods.

The following experiments were accordingly carried out during the season of 1925.

(*a*) *Experiment on the susceptibility of apple stocks and scions.*

Six trees of each of the varieties Worcester Pearmain, Bramley's Seedling,* James Grieve, Cox's Orange Pippin, on each of the apple stocks Malling Type I, Malling Type II, Malling Type V, Malling Type XII, were procured from a common source for the work.†

These particular varieties and stocks were selected as likely to show fairly wide ranges of susceptibility to leaf scorch.

Of the stocks Type V is considered highly susceptible, Type II fairly susceptible, Type I much less susceptible and Type XII possibly the least susceptible.

Among the varieties James Grieve and Cox's Orange Pippin are highly susceptible, Bramley's Seedling only slightly susceptible and Worcester Pearmain relatively resistant.

All the trees were planted in quartz sand in 10 in. waxed but unglazed plant pots during early January. At planting the stems were all cut back to a height of about 18 in. and all roots were treated in the Stringfellow method. The pots were placed in the open, a tarpaulin cover being placed over the top of each pot to protect the sand from the action of rain and sun. Throughout the experiment all trees were fed with a nutrient solution containing all the essential mineral elements excepting potassium to ensure scorching conditions.

(*b*) *Experiment on the relative susceptibilities of unworked apple root stocks.*

Ten trees of each of the above root stocks, unworked, were planted in sand in similar fashion to and simultaneously with the trees in experiment (a). Subsequently the ten trees of each stock type were divided into two groups of five trees each for differential nutrient treatment. The trees in one group were fed with a complete nutrient solution containing a relatively low amount of potassium and those in the other were given the nutrient solution devoid of potassium used in experiment (a).

The two nutrient treatments were given in this case to see whether, if in the event of the treatment "potassium omitted" proving too drastic to allow of

* No trees of this variety on Type V.

† Thanks are due to Mr. R. G. Hatton for supplying these.

differences due to stock susceptibilities being detected, such differences would be manifested under conditions less conducive to scorching.

Results.—In both experiments it was found that the trees on the four root stocks developed at markedly different rates depending on the rates of root formation and that the order of severity of scorching was determined by the relative rates of foliage development. Leaf scorch appeared on the trees when the leaves had reached similar stages of maturity. During the more advanced stages of scorching indications of the relative susceptibilities of the varieties were evidenced.

It seemed quite clear from the results that the experiments did not provide conditions to allow of comparing either the relative susceptibilities of varieties or of stocks or of the influence of stocks in rendering varieties susceptible or resistant to leaf scorch.

Before experiments along similar lines will yield such information it will be necessary to use large containers for the trees which will allow of continuation of the experiment over several seasons under which conditions the initial rate of root formation factor will be overcome.

PART III.—SOIL INVESTIGATIONS.

In the previous report on soils of leaf scorch centres (2) results of investigations at eleven centres were presented and discussed. It was pointed out on that occasion that in eight of the cases considered the soil textures were extremely open and the soils likely to possess very poor waterholding properties. Fruit trees at these centres were doubtless liable to suffer during droughty periods. In the other three cases the subsoils appeared to have unusually closely compacted structures and the view was expressed that the conditions in these subsoils were such as to hinder free root development and to produce poor soil aeration. The trees on these areas had poorly developed root systems and were often quite loose in the ground.

Since the publication of the above results it has been possible to extend greatly the soil investigations. In ninety-one of the cases of leaf scorch which have come to our notice the soil conditions occurring have been examined in the field and in the majority of these soil samples from the areas have been subjected to examination in the laboratory. These areas are located on several geological formations occurring in the West Midlands and in the S.E. Counties and the soils have been derived from rocks of widely differing composition. Thus centres have been examined on the following formations: Clay with Flints, Thanet Beds, London Clay, Chalk, Wealden Clay, Hastings Beds, Lower Greensand,

Inferior Oolite, Mid Lias, Lower Lias, Keuper Marl, Mountain Limestone, Old Red Sandstone, Wenlock Shale and on areas of Glacial Drift, River Gravel and Alluvium.

Although the soils show such diversity of origin it will be shown later that they possess certain characters which allow of their grouping into three classes for the purpose of considering their scorching tendencies.

In examining cases of scorch in the field, in addition to examining the soil conditions on the affected area, it has been the practice, wherever possible, to compare the conditions with those on adjoining "scorch free" areas. In treating the data obtained by this method it will be seen that the method has yielded information of great significance to the problem.

During the course of the last four years the writer has been engaged on soil survey work in the fruit growing areas situated on the Old Red Sandstone formation around Bromyard and Ross in Herefordshire and on the Lower Lias formation in the Pershore and Evesham districts of Worcestershire. These surveys have provided excellent opportunities for examining the distribution of leaf scorch over certain soil types and of determining the particular soil characteristics which are associated with scorching over the particular areas. This work has also rendered possible the making of numerous observations on "grass effect" on scorch and the carrying out of experiments with a view to determining ameliorative treatments which will be capable of application to numerous cases in the areas concerned.

For the purpose of discussing the main features which have been revealed by these investigations, the field notes* which have been obtained relative to forty-six leaf scorch areas are assembled in Table VII.

In this Table the centres are arranged in groups as follows :—

Bromyard Area : 1. Arable Plantations.
2. Grass Orchards.

Ross Area.

Bunter Drift Area.

Miscellaneous West Midlands Centres.

S.E. Counties Area.†

It is convenient to discuss the centres by these groups as such treatment enables certain centres providing similar problems to be considered together and this method is therefore adopted below.

* It was proposed originally to include two tables embodying the soil data from these centres in addition to the field notes in Table VII. but these were subsequently deleted owing to publication costs. The author will be pleased to lend copies of these to workers interested in the subject.

† The writer is indebted to Messrs. R. G. Hatton, N. H. Grubb and N. Bagenal for the locations of centres in this area.

TABLE VII.

Field Notes on Leaf Scorch Centres.

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
BROMYARD AREA.—ARABLE PLANTATIONS.				
1	Gentle slope to S.E.	Apples: Worcester Pearmain, Bismarck, Newton Wonder, Stirling Castle, Jas. Grieve, Lane's Prince Albert. Age 15 years. Stocks—Paradise. Trees stunted and loose in ground; have scorched since planting. Crops very small and of poor quality. Plantation unprofitable.	Surface soil close textured heavy silty loam. Sub-soil and below unweathered dry fine sandy material impervious to water.	Arable. Cultivation and general practice excellent. Manuring: Heavy dressings of organic manures containing nitrogen and phosphates.
1a	Do. Adjoins 1.	Bush Apples: Varieties, age, stocks as 1. Growth good; no scorch; crops satisfactory and of good quality.	Surface soil close textured silty loam. Sub-soil to 30in. moist and becomes more clayey downwards.	Do.
2	Knoll in centre of field. Medium to steep gradient from this point.	Bush Apples: Lane's Prince Albert chiefly and other commercial varieties. Age 20 years. Stocks: Free. Trees stunted, scorched and loose in ground. Crops small and of poor quality.	Surface soil close textured silty loam. Sub-soil dry silty material. At 18 in. dry unweathered sandy material impervious to water.	Do.
3	Steep slope to North.	Standard Apples: Newton, Bramley. Age 20 years. Stocks: Free. Standard Plums, Prolific, Czar. Age 10 years. Growth: All trees medium to poor. Apples: Scorch. Plums: Pale foliage.	Surface soil close textured silty loam. From sub-soil downwards dry unweathered silty material impervious to water occurs.	Do.
4	Fairly steep to S.E.	Standard Plums: Purple Pershore and Yellow Egg. Age 15 years. Growth very poor, foliage pale.	Surface close textured silty loam very tough to sample. Sub-soil and below dry unweathered fine sandy material impervious to water.	Arable. Cultivation and general practice excellent. Manuring: heavy dressings of organic manures containing nitrogen and phosphates.
5	Almost level.	Black Currants and Plums. Age 3 years. Black Currants: variety Baldwin. Poor growth and scorched foliage.	Surface close textured silty loam. Sub-soil to 30 in. close textured poorly weathered material and rather dry.	Do.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
6	Gentle slope to S.W.	Bush Apples: Bramley, Cox, Newton, Lane, Worcester. Age 15 years. Stocks: Paradise. Growth of trees only moderate. Foliage showed some scorch and yellowing.	Surface soil close textured silty loam. Sub-soil somewhat heavier. From 18 in. dry unweathered material impervious to water.	Since war allowed to tumble down to grass, pigged. Lack of cultivation showing effects.
7	Small knoll sloping to N., E., S.	Previously Half-Standard Apples. Commercial varieties. All varieties remained stunted, were loose in ground and badly scorched. Stocks: Free.	Surface soil close textured silty loam. Sub-soil and below dry unweathered silty material impervious to water.	Arable. Cultivation and general practice excellent. Manuring: heavy dressings of organic manures containing nitrogen and phosphates given, also some pit stable manure.
8	Small knoll in plantation from which ground slopes gently in all directions.	Standard Apples: Cox, Newton, Bramley, etc., interplanted with Raspberries and strawberries. Age 14 years. Stocks: Free. Growth all varieties very poor, trees loose in ground; leaf scorch bad since planting. Crops: Practically nil.	Surface soil close textured silty loam. Sub-soil very tough compact marl; below sub-soil dry unweathered silty material impervious to water. In places around the knoll patches where surface, sub-soil or below sub-soil consists of loosely packed sandy material.	Arable. Cultivation and general practice excellent. Manuring: Occasional dressings of organic manures containing nitrogen and phosphates.
9	Flat. Top of knoll.	Half Standard Apples interplanted with Strawberries. Varieties: Stirling Castle, Early Victoria, Grosvenor. Age 17 years. Stocks: Free. Trees all stunted; leaf scorch bad since planting; loose in ground. Crops very poor.	Surface soil close textured silty loam tough to sample. Sub-soil dry stiff unweathered marly material. Platey profile. Subject to water-logging.	Do.
10	Gentle slope to S.W.	Apples: Stirling Castle, Worcester, Warner's King, Newton. Age 19 years. Stocks Free. Plums: Yellow Egg. Age 1 to 3 ye s. Many apple trees regrafted because of previous failures. Much dying back; scorch bad and trees loose from planting. Crops: Practically nil since planting.	Surface soil and sub-soil sandy loam; below sub-soil to 30 in. loose fine sandy material overlying soft sandstone rock.	Do.
11	Gentle slope to S.	Bush Apples: Worcester and Cox interplanted with Strawberries. Age 14 years. Stocks: Paradise. Growth very poor; scorch and mildew bad. Crops: Worcester very poor; Cox practically nil.	Surface fine sandy loam overlying soft sandstone rock at from 9 in.	Arable. Cultivation and practice good. Manuring not heavy; pit stable manure and soot to the Strawberries.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
12	Flat top of knoll.	Half Standard Apples: Commercial varieties. Plums: Belle de Louvain, Prolific, etc. Age 19 years. Apples growth poor; loose in ground; scorched from planting. Crops very bad. Plums poor growth, foliage pale. Crops poor.	Surface and sub-soil fine sandy loam overlying soft sandstone rock at from 12 in.	Arable. Cultivation and general practice good until two years ago when area allowed to fall down to grass.
12a	Gentle slope to E.	Do.	Surface as 12. Sub-soil dry unweathered fine sandy material impervious to water.	Do.
13	Medium slope to W.	Standard Apples: Warner's King, Worcester, Claygate Pippin. Age 20 years. Stocks: Free. Plums: Belle de Louvain, Monarch, Prolific. Age 20 years. Growth and crops excellent.	Surface close textured silty loam. Sub-soil to 30 in. moist and rather more clayey.	Arable. Cultivation and general practice excellent. Manuring: Basic slag, lime and organic manures containing nitrogen and phosphates.
13a	Do.	Varieties, etc. as 13. Growth: Total failure to establish trees. Scorch bad.	Surface as 13. Sub-soil and below dry unweathered silty material impervious to water.	Do.
13b	Gentle slope to W.	Standard Apples: Bramley, Newton, Jas. Grieve, Worcester. Age 20 years. Stocks: Free. Plums: Czar, Yellow Egg, New Orleans, etc. Age 20 years. Growth and cropping excellent both fruits.	Surface close textured silty loam becoming more clayey to 30 in.	Arable. Cultivation and general practice excellent. Manuring: Basic slag, lime and organic manures containing nitrogen and phosphates.
13c	Flat top of ridge.	Apples and Plums: Varieties, etc. as 13b. Growth and cropping poor. Much scorch.	Surface close textured silty loam; Sub-soil dry unweathered silty material impervious to water.	Do.
13d	Gentle slope to W.	As 13c.	Surface soil to 30 in. varies in patches from close textured loam to loose sandy material.	Do.
BROMYARD AREA.—GRASS ORCHARDS.				
14	Practically level.	Standard Apples and Cherries. Various commercia varieties have been planted on several occasion and have always failed.	Surface close textured silty loam. Sub-soil dry unweathered fine sandy material impervious to water. Subject to waterlogging.	Grass orchard. Grazed with cattle fed with cake; otherwise not manured.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
15	Steep slope to E.	Standard Cherries: Various varieties. Age 20 to 30 years. Growth poor; trees unfruitful; liable to "die out."	Surface close-textured silty loam. Sub-soil ditto and very tough; below sub-soil dry unweathered silty material impervious to water.	Grass orchard grazed by cattle. Never manured.
16	Steep slope to S. and S.S.W.	Standard Cherries and Damsons. Age from 40 years. Trees all stunted and unfruitful. Cherries mostly die out. Foliage both fruits pale.	Surface tough poorly weathered silty loam. Sub-soil and below dry unweathered silty material impervious to water.	Grass orchard grazed by cattle. Very little manure applied.
17	Flat top of hill.	Standard Apples: Blenheim and Prince's Pippin. Age 20 years. Stocks: Free. Original trees have mostly died out, those remaining are stunted and unprofitable. Foliage pale.	Surface close textured silty material. Sub-soil and below dry fine sandy material impervious to water.	Grass orchard grazed by cattle. Occasionally dressed with basic slag.
ROSS AREA.				
18	Gentle slope to N.W.	Bush Apples: Beauty of Bath, Worcester, Jas. Grieve, Cox, Bramley, Grenadier, Lane. Age 12 years. Stocks all Paradise, except Lane, free. Growth excellent and trees have cropped well.	Surface and sub-soil generally coarse sand. At depths varying from 18 in. to 30 in. a bed of moist marl occurs.	Arable. Cultivation and general practice excellent until two years ago. Since then cultivation poor but recently renewed. Manuring: Pit stable manure at planting; since then occasional meat and bone and shoddy.
18a	Do.	Bush Apples. Varieties as 18, but mostly Lanes. Trees stunted; have scorched from planting. Crops very poor. Trees have ceased to scorch since cultivation ceased.	Soil to 30 in. coarse sand; below 30 in. sandy or soft sandstone rock.	As 18.
18b	Practically level.	Bush Apples: Jas. Grieve, Worcester, Cox, Bramley, Lane. Age 12 years. Stocks: Paradise, except for Lane's, free. Growth and cropping excellent.	Coarse sand in surface and sub-soil. Marl underlies at depths from 18 in. to 30 in.	As 18.
18c	Do.	Bush Apples: Varieties, etc. as 18b. Trees stunted and badly scorched since planting. Crops very poor. Scorch has disappeared since cultivation ceased.	Surface and sub-soil generally coarse sand. At depths from 9 in. soft sandstone rock occurs.	As 18.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
19	Do.	Bush and Standard Apples: Various varieties, chiefly Worcester, Warner, Lane. Age from 40 years. Stocks: Mostly Free. Growth and cropping excellent.	As 18.	Arable. Cultivation and practice good. Manuring fairly liberal with organic manures such as meat and bone. Limed occasionally. Recently pigged.
19a	Do.	Bush Apples: Various varieties, chiefly Grosvenor, Derby. Age from 30 years. Stocks probably both free and Paradise. All trees stunted and scorched badly from early age. Crops very poor.	As 18a.	As 19.
20	Medium slope to S.W.	Bush Apples: Numerous commercial varieties. Age 25 years. Stocks mostly Paradise, some free. Growth has been fairly good but much restricted by pruning. Foliage and crops good.	Soil generally coarse sand to 30 in. with admixture of marl.	Arable. Cultivation and general practice good. Fairly liberal treatment with organic manures of meat and bone type of recent years.
20a	Medium slope to S.W.	Bush Apples: Varieties, etc. as 20. Growth stunted and trees often complete failures. Scorch bad since early age. Crops poor.	As 18a.	As 20.
BUNTER DRIFT AREA.				
21	Level.	Bush Apples interplanted with market garden crops. Varieties: Worcester, Grosvenor, Newton, Bramley etc. Trees always stunted, badly scorched and crops poor and useless. Grubbed after 12 years. Stocks Paradise.	Coarse gravel sand mixture to 6 ft. over-lying blue lias clay.	Intensive market garden cropping. Heavily manured with shoddy, meat and bone manures.
22	Level.	Bush Apples: Various commercial varieties many Worcesters, Newton, Cox, Grosvenor. Age 20 to 12 years. Stocks: Mostly Paradise. Growth medium; often badly scorched. Crops only medium to poor. Plums mostly Victorias, Yellow Egg, Purple Pershore. Age as apples. Growth medium; often show pale foliage.	Coarse gravel and sand mixture to various depths from from 3 ft., overlying blue lias clay.	Arable. Cultivation moderate and often poor. Not previously systematically manured. Occasionally organic manures and some stable manure.
23	Level.	Bush Apples interplanted with market garden crops. Various commercial varieties. Age unknown. Stocks: Paradise.	Coarse sand to depth of several feet over blue lias clay.	Intensive market garden cropping. Manuring: Organic manures of meat and bone type.
24	Level.	Gooseberries: Variety, Careless and young Plums mostly Purple Pershore. Age from 4 years. Gooseberries fair growth but show scorch each season. Plums are not starting very satisfactorily.	Coarse gravel and sand mixture to depth of auger.	Arable. Cultivation and general practice good. Manuring: Very little to date. Some organic manures, fish, meat.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
24a	Level.	Gooseberry and Plum varieties, etc. as 24. Growth of Gooseberries very poor and stunted. Scorch bad. Crops very poor.	As 24.	As 24.
25	Level.	Nursery Stock: Apples, Plums, Pears, Gooseberries, Black Currants. First season or two after planting much scorch on all sorts of stocks. Now grows excellent trees and bushes since manuring with potash.	Coarse sand and gravel of great depth.	Intensive nursery practice followed. Has been manured heavily with sulphate of potash since scorch appeared. Organic manures such as fish and meat also given.
26	Level.	Black Currants: Seabrook's Black. Age 4 years. Growth good and fruiting satisfactory. Some scorch where drift deeper.	Coarse gravel-sand mixture to depths from 2 ft. to 6 in. overlying close textured Keuper Marl.	Arable. Cultivation and general practice good. Manuring: Stable manure at planting; since then liberal dressings of organic manures—fish, meat and bone.
26a	Level. Adjoins 26.	Black Currants: Baldwin. Gooseberries: Whinham's Industry. All bushes poor growth and bad scorch. All aged 4 years. Baldwins unable to ripen fruits.	Coarse gravel-sand mixture to depth of several feet.	As 26.
MISCELLANEOUS WEST MIDLANDS AREAS.				
27	Level.	Bush Apples: Worcester, Stirling Castle, Jas. Grieve. Age 15 to 20 years. Stocks: Crab and Paradise. Growth is variable possibly largely due to stocks. Jas. Grieve always bad scorch; other varieties not so badly affected. Until 1922 growth bad; scorch bad and crops poor. Gooseberries interplanted, now grubbed, made bad growth and scorched badly.	Heavy clay surface and subsoil containing some coarse sand drift material. Liable to lie wet.	Arable. Cultivation and practice now good. Previously only moderate. Practically no manuring done previous to 1922.
28	Level.	Standard and Bush Apples: Various commercial varieties mostly standards on free stock including Cox, Worcester, Newton, Grosvenor. Age probably 20 years. All varieties scorch badly over certain areas and trees often stunted and only bear worthless fruits.	Similar 27.	Arable. Cultivation and practice only moderate. Manuring: Hoof, meat meal, bone manures had been occasionally applied.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
29	Gentle slope to E.	Plums: Yellow Egg and Warwickshire Drooper. Age 7 years. Gooseberries: Mostly Whinham, interplanted. Plums and Gooseberries have died out completely in large patches in the field. In certain areas growth is good.	Surface soil and below to great depth, very heavy brown lias clay. On bad sections of field the soil is waterlogged to depth of 3 ft.	Arable. Cultivation and general practice good. Previous to planting very deeply subsoiled which has resulted in waterlogged areas. Manuring: heavily manured with soot and organic manures such as meatmeal, bones, etc.
30	Level.	Bush Apples: Worcester, Cox, Lady Sudeley, Bramley, etc. Age 25 to 30 years. Stocks: Paradise. Growth stunted and scorch bad from planting until two or three years ago when plantation grassed down.	Surface and sub-soil loose textured silty loam; below 18 in. close textured rather impervious marl.	Grass orchard since 1922. Grass is cut during summer and left as a mulch around the trees. Previous to grassing cultivation excellent. General practice excellent. Manuring basic slag occasionally.
31	Gentle to E. Located near bottom of slope.	Bush Apples: Cox and Rival as espaliers on Paradise interplanted between. Plums: Purple Pershore. Age approx. 17 years. Growth has been fairly good but apples have scorched badly of late years and plums often show pale foliage and give poor fruit.	Soil down to 30 in. is a fine sandy loam.	Arable. Cultivation and general practice excellent. Manuring: Probably very little manure given since planting.
31a	Do.	Standard Plums: Mostly Purple Pershore, also Monarch and Prolific. Partly interplanted with Black Currants. Plums generally have made poor growth, have pale foliage, are loose in ground. They crop heavily but fruit of moderate quality. Black Currants: Baldwin, have made excellent growth.	Surface soil fine sandy loam. Sub-soil dry unweathered silty material impervious to water.	As 31. Intercrops are well manured chiefly with organic manures.
32	Level.	Bush Apples: Jas. Grieve, Lord Derby. Age approx. 17 years. Stocks: Paradise. Growth is patchy; some trees especially of Derby have remained small and stunted. Trees of all sizes have shown varying degrees of scorch.	Surface a close textured loam. Sub-soil varies over the plot showing patches of sand and clay. Material in sub-soil and below often wet when sampled.	As 31.
33	Medium slope to S.	Bush apples: Various commercial varieties. Age about 10 years; planted when about eight years old. Stocks: Variable. Trees in poor condition; scorch severe. Interplanted with Raspberries and Strawberries. Raspberries: Poor growth and scorched.	Surface soil very stony and texture coarse; Sub-soil and below sub-soil more stony than surface and texture very open.	Arable. Cultivation and practice fair. Manuring: Strawberries had been dressed heavily with stable manure. otherwise no manure applied,

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
34	Level.	Standard and Bush Apples: Varieties, Lane, Allington, Newton, Bramley, Cox, etc. Age 10 years. Stocks: Paradise and Free. Until 1921 trees mostly stunted and badly scorched and crops moderate. Since 1921 scorch practically disappeared. Some trees low in vigour from grass effects.	Light fine sandy soil of great depth. Occasional patches of clayey material in sub-soil.	Part of area cultivated and part under rough ungrazed grass. Practice only moderate. Manuring: Previous to 1921 some liquid manure occasionally given. Since then liberal dressings of Kainit. Grassed portion folded with fowls.
35	Level.	Bush Apples: Worcester, Allington, Cox, Jas. Grieve, Newton. Age 6 years. Stocks: Paradise. Trees from planting to three years bad growth and stunted with bad leaf scorch. At present growth generally fairly good and crops good. Some trees still scorch. Interplanted with garden crops and partly used as nursery for forest trees.	Extremely gravelly soil. Matrix light sandy loam.	Arable. Cultivation and general practice moderate. Manuring: Kainit applied occasionally since 1921.
36	Medium slope to W.	Half Standard Apples and Plums. Age 20 years. Apples: Grenadier on Free Stocks. Plums: Victoria. Stocks unknown. Growth of Apples has always been moderate. They have mostly scorched badly for many years. Plums have grown fairly well and cropped heavily.	Fine sandy loam to depth of auger. Rather sandy in patches and contains large pieces of limestone debris.	For many years cultivation and general practice excellent. Of late years plot has been allowed to go down to grass and has been pigged. Manuring: previously liberally treated with organic manure such as bone and meat with some pit stable manure.
37	Gentle slope to S.E.	Gooseberries: Variety, Keepsake. Age 6 years. Growth good; crops good. Bushes used in a manurial experiment.	Surface and sub-soil fine sandy loam overlying marl.	Arable. Cultivation and general practice good. Manuring: Series of plots differently manured.
37a	Do. situated below 37.	Gooseberries: Variety, Keepsake. Age 6 years. Growth good where complete manures given. Where potash omitted bushes stunted and failures with bad scorch since planting.	Surface and sub-soil more sandy than 37.	As 37.
38	Practically level. Top of a slope.	Bush Apples: Various commercial varieties including Worcester, Newton, Lane. Age 4 years. Stocks: Paradise. Trees making excellent growth and foliage excellent. Gooseberries interplanted; excellent growth and cropping.	Soil stony containing large pieces of oolitic limestone; matrix fine sandy loam to depth of 18 in. overlying oolitic brash.	Arable. Cultivation and general practice excellent. Manuring: Pig manure and artificials liberally used.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
38a	Fairly steep slope to S.E. on slope below 38.	Bush Apples, mostly Lane's Prince Albert and Gooseberries as 38. Growth of Apples, medium and show scorch. Gooseberries: Poor growth in patches and scorched foliage.	As 38, but soil much more shallow; limestone brash at 9 in.	As 38.
S.E. AREA.				
39	Level.	Bush Apples: Various varieties, interplanted with black currants. Apples: Age 7 years. Stocks: various Paradise. Plot used as stock trial plot. Growth generally good and foliage good. Few trees growth only medium. Black Currants excellent growth.	Sandy loam with fair amount of clay below 18 ins. In patches rather more sandy.	Arable. Cultivation and general practice excellent. Manuring: liberal dressings London dung and organic manures.
39a	Level. Adjoins 39.	Bush Apples: various varieties. Age 7 years. Stocks: Various Paradise and Crab. Some trees on this plot have scorched each year since planting.	As 39. Sandy material with rock at 30 ins. under scorched tree.	As 39.
40	Level.	Standard and Bush Apple trees. Age 20 to 12 years. Stocks: Free and Paradise. Trees all stunted and have scorched badly for years. Cropping bad.	Sandy loam to 30 ins. over sandstone rock.	Arable. Cultivation and general practice probably good. Manuring: Not known.
41	Gentle slope to E.	Bush Apples and Pears of various varieties interplanted with Gooseberries. Age 2 years. Apple stocks: Not known. Pears mostly making good growth. Many apples have remained stagnant and badly scorched. Gooseberries very poor in patches and showing bad scorch.	Fine sandy soil with little cohesive properties to depth of auger.	Arable. Culitivation and general practice excellent. Manuring: Not known.
42	Practically level. Top of slope.	Bush Apples, mostly Bramley and Miller's Seedling. Age probably 20 to 12 years. Stocks: Not known, probably Paradise. Trees have made fairly good growth. A little scorch; crops fairly good.	Light sandy loam to depth of auger overlying chalk.	Probably cultivation and general practice good in past. Recently put down to grass and run with geese. Manuring: Probably organic manures such as shoddy, bones, etc.
42a	Practically level. Bottom of slope below 42	Bush Apples, mostly Worcester and Lane. Age, etc. as 42. Trees stunted, badly scorched and branches dying back. Crops bad.	As 42.	As 42.

TABLE VII.—*Continued.*

Plantation or Orchard Area.	Site.	Particulars of Trees, Bushes, etc.	Soil.	Management.
43	Level.	Bush Apples: Lady Sudeley. Age 12 years. Stocks: Unknown. Trees well grown; foliage and crops good.	Surface sandy loam becoming heavier to 30 in. depth.	Arable. Cultivation and general practice good. Manuring: Liberal dressings of organic manures, shoddy, bones, etc.
43a	Level. Adjoins 43.	Bush Apples: Cox and Worcester. Age 12 years. Stocks: Unknown. Trees all stunted and scorch badly each year. Crops practically nil.	Surface a light sand becoming more sandy to depth of auger.	As 43a.
44	Level.	Bush Apples: Various commercial varieties. Age unknown, but over 10 years. Stocks: Unknown. Trees excellent growth and foliage and crops good.	Sandy loam to depth of auger.	Arable. Cultivation and general practice excellent. Manuring not known.
44a	Level. Adjoins 44.	Bush Apples as 44. Trees all stunted and have always scorched badly. Foliage now showing grass effects.	Surface soil tough clay with flints. Overlies chalk at 9in. to 18 in. depth.	Cultivation and general practice as 44 in past, but now down to grass and not much looked after.
45	Practically level.	Red Currants, Gooseberries and Young Plums and cherries. Age 2 years. Plums and Cherries look healthy. Gooseberries and Red Currants stunted and badly scorched.	Sandy loam, very flinty to 18 ins. Overlies chalk at various depths.	Arable. Cultivation and management good. Manuring: complete artificials for interplanted mangels.
46	Level. Below level of surrounding country.	Bush Apples: Various varieties. Age 15 years. Stocks: Not known. Trees in many cases have scarcely grown since planting. Have scorched each year.	Silty loam to 30 ins. with patches of tough red clay.	At present plantation down to grass and management poor. Manuring: Not known.

Bromyard Area.

The designation Bromyard area was given to one of the Old Red Sandstone areas over which a survey of fruit soils was carried out recently.* This area covers approximately 200 square miles and is mostly included in the roughly rectangular area enclosed by lines joining Berrington Mill, Worcestershire, in the north west, Stockton-on-Teme, Worcestershire, in the north east, Ledbury, Herefordshire, in the south east and Holmer, Herefordshire in the south west. The remainder of the area is comprised of a narrow strip of country only a mile or two in width extending from Ledbury, Herefordshire, in the north to Underdean, Gloucestershire, in the south. The surface rocks over practically the whole of the area belong to the Lower Division of the Old Red Sandstone formation and only plantations and orchards in which the soil is derived from these rocks were considered in the survey.

The rocks are composed chiefly of clays, marls and cornstones with occasional beds of close textured soft micaceous sandstone. The soil of the area is, in general, a close-textured silty loam, generally devoid of stones and is underlain by marl. It is regarded locally as a heavy soil. In the neighbourhood of the sandstone beds the soil is usually lighter and in such areas may be quite a light sand.

The district is a famous West Midlands fruit growing area and there are many magnificent orchards of apples and cherries distributed over it.

As the result of the survey it was found possible to classify the soils occurring in the plantations and orchards of the area on the basis of certain field characters and textural features as shown by mechanical analyses as under.

Class A. The Predominant Class of the Area.

The surface soils are close-textured silty loams, pink in colour when dry and brick red when wet. Stones are generally absent but a small percentage of sandstone fragments or cornstone nodules may be present. The soil samples easily with an auger and it is usual to find that the successive layers of subsoil are more clayey than those immediately above until finally the typical stiff marl of the parent rock is reached.

The gradation from the close-textured surface soil down to the marl at a depth below 30 in. is a characteristic feature of the group.

Of the mechanical fractions, fine gravel and coarse sand usually comprise less than 5 per cent. fine sand, silt and fine silt are important fractions and clay in the surface soil ranges from 8.5 per cent. to 17.5 per cent. whilst at 18 in. to 30 in. depth this fraction constitutes from 12 per cent. to 22 per cent.

* Fruit Soils Survey.—West Midlands Area, by T. Wallace, G. T. Spinks, E. Ball. Report to the Ministry of Agriculture and Fisheries, December, 1926.

Class B. Includes several sub-classes or divisions showing characters which differentiate them from Class A.

Division B.1. Special feature: The development of stiff bands of marl at or near the surface.

The condition is usually met with on knolls or portions of slopes where the curvature is convex. It is doubtless the result of active periodic erosion of the surface soil layers. The bands are impervious to water and mark the lower limit of the pedological processes.

The surface soils are usually of closer texture than in group A. and the marl layer contains a high percentage of clay.

Division B.2. Special feature: Shallow soil overlying unweathered material of a fine sandy or silty character.

These conditions generally occur under the same circumstances as B.1. and are most probably due to the same agencies. The unweathered material *in situ* is impervious to water but when excavated and placed in water it easily falls to pieces. The structure of the profile of this material is "platey." The impervious character appears to be due to the absence of coarse particles and to the shape and arrangement of the particles. There is no iron pan present. The soils may show any one of the following "irregular" features in proceeding from the surface soil to depths of 30 in. or 42 in.:

a. Sharp rise in "fine sand" accompanied with a fall in clay.

b. Sharp rise in "silt" accompanied with a fall in clay.

c. Irregular decrease in the clay fraction only.

d. Sharp rise in the "fine sand" only.

e. Decided fall in "fine sand" with sharp rise in "fine silt."

Division B.3. Special feature: Sandy pockets of loosely packed particles which offer very little resistance to the auger.

These pockets often occur near the outskirts of areas in B.2. and are possibly formed from the natural panning of coarser particles in the formation of the particular condition in B.2.

The surface soils usually have textures as in A. Abnormal material occurs which contains a high percentage of "fine sand."

Division B.4. Special feature: Shallow soil of stiff marly character overlying cornstone deposits.

This condition occurs in situations as in B.2. and is very similar to it. The point of difference is the character of the underlying rock.

Division B.5. Special feature: Shallow soil overlying soft sandstone rock.

The surface soil may be close-textured as in Class A. with a more sandy subsoil or it may be sandy and contain fragments of sandstone rock.

In the more extreme sandy cases the soil may contain over 60 per cent. of fine sand, whilst the percentage of clay is much lower than in Class A.

Division B.6. Special feature: The soil from the surface to 30 *in. depth or more is of a light fine sandy nature.*

These areas generally occur in the vicinities of sandstone outcrops. The soil to 30 in. is much lighter than in group A. Fine sand is high, silt and fine silt tend to be low and clay is always low.

On examining the growth characters of the various sorts of fruit trees and bushes occurring in the plantations and orchards in the area in relation to the soil conditions obtaining, in each case, it was found that a close correlation existed between growth features and the soil characters of the various classes shown above. Where the conditions in class A. were present, growth was invariably excellent, whereas where those in Divisions 1, 2, 3, and 4 of Class B. occurred trees and bushes either failed entirely or were only poor in vigour. Where the soils of the character of Divisions 5 and 6 of Class B. occurred, cherries were usually highly successful whereas apples often failed badly.

In all cases of failure or poor growth in the case of apples and bush fruits growing under arable conditions the trees and bushes were either affected with leaf scorch to a serious extent or had suffered so badly previously that they had reached the small leaf stage into which such trees degenerate and were

TABLE VIII.

Showing Classification of Soil Areas in the Bromyard Area.

Arable Plantations.	Plantation or Orchard Area.
CLASS A.	
1.	1a, 12b, 13, 13b.
CLASS B.	
1.	9.
2.	1, 2, 3, 4, 5, 6, 7, 8, 12a, 12c, 13a, 13c.
3.	8a, 13d.
5.	10, 11, 12.
Grass Orchards.	
CLASS B.	
2.	14, 15, 16, 17.

stunted and practically valueless. Further, where growth was good as on Class A. soils, leaf scorch was either entirely absent or of no consequence.

The examples given from this area in Table VII. are shown on the opposite page in their respective soil classes in Table VIII. In connection with this latter table it should be stated that only very few cases of Class A. are given owing to limitations of space.

There are several points to which attention should be drawn in connection with these cases.

In the first place we have here examples of different sets of soil conditions on which certain kinds of fruit trees invariably suffer from leaf scorch.

In Divisions 1, 2 and 4 of Class B. the feature common to the soils is a shallow surface soil overlying an impervious unweathered subsoil. Trees growing on such soils are likely to suffer in the following ways.

1. Great resistance is offered to free root development.
2. Where the surface is level the soil overlying the unweathered material is subject to waterlogging.
3. The soil dries out quickly in dry periods.
4. The soil is likely to be poorly supplied with available plant food owing to defective weathering.

It should be noted that waterlogging does invariably occur to some extent over level areas under these conditions but in many cases on slopes this is not so and hence waterlogging is not the only cause of leaf scorch in such cases.

Where soil conditions such as in Divisions B3, 5, and 6 obtain, unless the permanent water-table is high, trees on such areas are likely to suffer from lack of water during periods of drought.

Secondly, it is important to note that leaf scorch does not occur in grass orchards such as those given in the tables but nevertheless the trees are invariably failures. This point is discussed further in Part IV.

Certain points in the chemical data of the soils of these areas require mention. In all cases where "total" potash and phosphoric acid have been determined the values obtained for potash are relatively high—1.30 per cent. to 0.50 per cent.—whilst those for phosphoric acid are only moderate to poor—0.16 per cent. to 0.05 per cent. The "available" potash figures are seldom high—highest surface soil value is 0.0194 per cent.—and are frequently low—usually 0.010 per cent. to 0.0050 per cent. In many cases "available" phosphoric acid is relatively high in the surface soil—over 0.04 per cent.—which is doubtless the result of the practice in the area of applying heavy dressings of phosphatic manures. There is generally a small percentage of carbonate of lime present in both surface and subsoil—usually less than 0.50 per cent. and in no case is any sample strongly acid—highest "lime requirement," 0.119 per cent.

From such a case as 13b., where available potash in the surface soil is 0.0093 per cent. and in the subsoil 0.0068 per cent., it seems quite possible to have excellent tree growth free from leaf scorch with a relatively low "available" potash in the soil. Many such cases of Class A. soils in the area can be quoted.

Ross Area.

This area comprises a few square miles around the town of Ross in Herefordshire. The soil other than on the alluvial tract bordering the River Wye which flows through the district is generally of a coarse textured sandy nature. It is derived from the underlying rock which is a soft coarse grained sandstone containing quartzose grits and exhibiting much false bedding. Occasional lozenge shaped bands of marl occur between the layers of sandstone.

The soil conditions occurring in the fruit plantations of the area have been classified as follows :

Class A. The surface soil and subsoil are of a coarse sandy texture, are pink in colour when dry and brick red when wet. The sandy material overlies a bed of red marl which occurs at depths varying from 15 in. to 3 ft. 6 in. The appearance of the marl is similar to that occurring in the Bromyard area.

Class B. The surface soil and subsoil are mixtures of coarse sand and marl and are appreciably stiffer than the sandy soil in Class A. The subsoil rests on soft sandstone rock.

Class C. Surface soil and subsoil to at least 4 ft. 6 in. consist of coarse sandy material as in the surface soil of A. Marl is absent.

Class D. The surface soil and subsoil (where present) consist of coarse sandy material as in A. and overlie soft sandstone rock which occurs within 30 in. of the surface.

In this area it was found that trees growing on areas in Classes A. and B. were invariably successful and free from leaf scorch whilst those on areas in Classes C. and D. were generally poor in vigour or total failures and always either badly scorched or had reached the small leaf stage after several seasons of scorching.

The examples provided in Table VII. fall into the above classes as under :

Class A.—Nos. 18, 18b, 19, 20.

Class D.—Nos. 18a, 18c, 19a, 20a.

In the cases of leaf scorch in this area it will be readily seen that the soil conditions associated with the trouble—Classes C. and D.—are likely to be conducive to rapid drying out of the soils in dry periods and that where trees develop without scorching the soil conditions are likely to possess better water-supplying properties in seasons of drought.

The chemical data show that " total " potash and phosphoric acid are both on the low side in these soils—in surface soils potash usually below 0.50 per cent. and phosphoric acid below 0.10 per cent. " Available " potash may be very low or of medium value on both good and bad areas—surface soils 0.015 per cent. to 0.0050 per cent.—but in no case is it really high. " Available " phosphoric acid is usually fairly high as the result of manurial treatment—surface soils generally above 0.020 per cent. The majority of the soils contain a small percentage of carbonate of lime—generally less than 0.50 per cent.—and a few show a small " lime requirement "—never higher than 0.10 per cent.

BUNTER DRIFT SOILS.

These soils extend over a considerable area in the Midlands, in Warwickshire, Worcestershire and Gloucestershire.

The drift material is extremely coarse, consisting largely of pebbles and coarse sand. In the fruit growing areas around Pershore, Evesham and northern Gloucestershire the drift overlies the Keuper Marl and Lower Lias formations. The depth of the deposit varies greatly over the area. In some places it is several feet deep and at others the presence of the characteristic pebbles embedded in the close-textured sedentary soils is the only visible indication of its presence. In certain areas as in the regions bordering on the valleys of the Warwickshire Avon and the Severn the original deposit has been thoroughly re-sorted by river action and at present contributes to a series of terraces of river gravels.

In most of the fruit plantations of the area it is usual to find much soil variation: at certain points the Keuper or Lias soils occur in practically unaltered condition whilst a short distance away the soil to a considerable depth consists entirely of the coarse " drift " material.

Observations carried out over the area have shown that trees and bushes growing on areas of deep undiluted drift usually " do " very badly and frequently fail entirely. Leaf scorch is the characteristic symptom exhibited by apples, currants, gooseberries and strawberries in such cases of failure whilst plums generally carry very pale foliage which may finally pass into a scorched condition.

Data from eight soil areas are given in Table VII. Of these areas only on No. 26 have fruit bushes made satisfactory growth without special measures having been taken. This area and No. 26a. adjoin and on the latter, where the drift is deeper than on the former, crops were failing entirely previous to the adoption of special manurial treatment, whereas on No. 26 growth and cropping were satisfactory. It will be observed from the notes for these two centres that the soil at 26a. is much more open in texture than at 26.

Mechanical analyses data for all the soils in this group show that they contain very high proportions of stones and coarse sand and that the textures are such as to allow of rapid drying out under summer conditions.

The chemical data available on these soils show that in the cases in which " total " potash and phosphoric acid have been determined, the values for potash are low—usually below 0.30 per cent.—excepting in 26—0.71 per cent.—where an appreciable proportion of Keuper material is present whilst those for phosphoric acid are fairly average figures for arable soils—0.20 per cent. approximately—except in the case of 21 where the values are high—0.326 per cent. in surface soil—due to previous heavy phosphatic manuring.

" Available " potash is never high—surface soil often less than 0.01 per cent., although the values for 21 and 22 tend to be so—highest value 0.0181 per cent.—and in certain cases is definitely low. It is interesting to compare the two cases 24 and 24a in which the textures are similar and where the degrees of scorching differ appreciably, the " available " potash on the better area, 24—0.0116 per cent. and 0.0106 per cent. for surface and subsoil respectively as against 0.0062 per cent. and 0.0052 per cent. on the poorer area 24a. It should be noted, however, that the " lime requirement " values vary in the opposite direction 0.019 per cent. and nil for the better area and 0.136 per cent. and 0.116 per cent. for the poorer area although it may be mentioned that up to the present time no relation between leaf scorch and soil acidity has been found.

The values for " available " phosphoric acid range from exceedingly high figures to values ordinarily present in arable soils—0.140 per cent. to 0.11 per cent. At all centres the soils either contain small percentages of carbonate of lime—below 0.30 per cent.—or show small " lime requirements "—highest value 0.15 per cent.

Miscellaneous West Midland Centres.

The points of importance in the soils of this group can be discussed most readily by considering certain genetically related cases together and by grouping together others not so related but showing important characters in common. In a few instances it is necessary to treat the cases separately.

At centres 27, 28 and 29 the soils consist largely of Lower Lias Clay, especially at the last of these where drift is practically absent.

It has not been usual to find cases of leaf scorch occurring under the conditions obtaining at these centres and indeed at the last of these the condition has doubtless been induced by an error in the drainage scheme which has resulted in the partial waterlogging of the area. At this centre leaf scorch is only present on waterlogged tracts and where there is no waterlogging the trees and bushes are in excellent condition and free from scorch.

At centres 27 and 28, drainage conditions in the past have undoubtedly been poor and the land appears to have suffered in consequence. These conditions have been greatly improved at 27 during the last few seasons and this treatment coupled with generous manurial treatment has resulted in very marked improvements in the trees. Leaf scorch has been greatly mitigated and the plantation has been converted from a financial burden into a profitable undertaking.

Centre 28 probably still suffers badly from unsatisfactory drainage conditions, the site being relatively low and flat and difficult to drain efficiently. An opportunity has not occurred to investigate the conditions very closely. The value obtained for " available " potash in the surface soil—0.0092 per cent.—is unusually low for this class of soil.

The soil conditions at Centre 30 are similar to those present at certain scorch areas in the Bromyard district, the surface soil being a close-textured loam which overlies a relatively poorly weathered subsoil. The subsoil sample shows a sharp rise in fine sand over the surface soil and below the subsoil there is also a sharp rise in clay. As in the cases in the Bromyard area the available potash is low at the centre—0.0086 per cent. In passing it should be mentioned that the conditions in the subsoil at this centre do not appear as unfavourable as many examined in the Bromyard area. These conditions, however, are of frequent occurrence in the more silty soils of the Keuper formation and produce effects identical with those previously recorded in the Old Red Sandstone area. In fact the presence of unweathered subsoils appears to be of common occurrence in silty soils of several geological formations and in the writer's experience is invariably associated with infertility. Similar observations on silt soils in the U.S.A. are recorded by Hilgard.*

There is nothing very striking in the soil texture at Centre 31, but the chemical analyses suggest that the land is in poor heart. " Available " potash and phosphate are both low—surface soil 0.0056 per cent. K_2O, 0.0079 per cent. P_2O_5, and there is a substantial " lime requirement "—0.30 per cent. This centre is discussed further in Part IV.

31a adjoins 31, and is a further case of an unweathered silty subsoil which is quite impervious to water. On this area plum trees have failed to root adequately and are quite loose in the ground and carry very pale foliage of poor quality.

The surface soil at 32 is a close textured loam. Although the area covers less than half an acre the subsoil shows much variation. In places it consists of open-textured sandy material, at others dry unweathered silty material is present which overlies stiff dry impervious marl and adjoining the latter area it is composed of wet clay to the depth of 2ft. 6in. Drainage conditions do not

* Hilgard, E.W.—Soils, pp. 102, 103. The Macmillan Coy. 1912.

appear to be good, especially over the wet subsoil area and in carrying out the soil examination the opinion was formed that the wet condition of this particular area was due to water failing to penetrate the impervious subsoil of the adjoining area and subsequently collecting in the more pervious material.

The distribution of leaf scorch in this plantation has been recorded since 1922 and it has been noted that the scorched trees have been mostly located on the area possessing the wet subsoil. (See later, Part IV.)

The soil data obtained relating to this area were obtained on samples from the heavier subsoil sections.

The figure for " available " potash in the surface soil—0.0154 per cent.—may have little significance since the area had received heavy dressings of sulphate of potash for four consecutive seasons previous to sampling. A dressing of lime had also been previously applied.

Nos. 33, 34 and 35 may be considered together as being all cases of very light soils, easily affected by drought. Nos. 33 and 35 are extremely stony, whilst 34 is stoneless but owes its open texture to the large percentage of fine sand which it contains. The values obtained for " available " potash in the samples from 33 —surface soil 0.0051 per cent., subsoil 0.0242 per cent.—appear peculiar, that in the surface soil being much lower than in the subsoil. They have been verified on duplicate samples. A possible explanation of the result is that the land had been previously used as grassland for many years, which treatment has possibly greatly depleted the store of " available " potash in the surface soil which is naturally high in this class of granitic soil. " Available " potash at the other two centres is of the medium order—0.0133 per cent. and 0.0117 per cent. The values for " available " phosphoric acid are all satisfactory, being high at 34—surface soil 0.0916 per cent. The samples from 33 show substantial " lime requirements "—0.492 per cent., 0.128 per cent.—but at the other centres the soils contain large supplies of carbonate of lime—surface soils 5.5 per cent. and 2.5 per cent. respectively.

The soil at Centre 36 does not show any marked peculiarity in texture when submitted to mechanical analysis, though actually in the field the soil feels rather " loose," does not " tread " firmly and works rather puffily. Much of the material composing the soil is material which has been washed down the hillside from higher levels. " Available " potash is fair in amount—0.118 per cent.—and " available " phosphoric acid is good—0.0290 per cent.— in the surface soil, possibly due to previous manuring. The soil is naturally well supplied with carbonate of lime as a proportion of it is derived from beds of Silurian limestone.

Nos. 37 and 37a require consideration together. These samples are from adjoining-areas. No. 37 is situated above 37a, and the soil of the latter area is composed chiefly of material washed down from area 37. Gooseberry bushes have failed to grow without manure on area 37a, and are totally crippled with

leaf scorch, whilst on 37 bushes of the same variety, planted simultaneously with those on 37a, have grown well without manure and have exhibited leaf scorch only very slightly.

Comparison of the textures of the surface soils shows that the soil on 37a is much more open in texture than on 37. Although analytical data are not available for the subsoils the difference between these is of the same order as in the surface soils.

On these areas there are marked differences in " total " potash and in " available " potash, the latter being low at 37—0.0092 per cent.—as well as at 37a—0.0064 per cent. Both soils showed " lime requirements " when sampled, but were limed previous to planting the gooseberry bushes.

Centres 38 and 38a also allow of comparison of soil conditions on adjoining scorch and non-scorch areas, and here again on the " scorch " area, 38a, the soil is lighter and thinner than at 38 and in consequence more susceptible to drying out conditions.

The samples from these centres yield extremely low values for " available " potash and " available " phosphoric acid—K_2O 0.0034 per cent., 0.0026 per cent.; P_2O_5 0.0013 per cent., 0.0016 per cent.—whilst they contain very large amounts of carbonate of lime—17.0 per cent. and 31.5 per cent.—derived from the parent rock.

SOUTH-EASTERN AREA CENTRES.

It is convenient to group these centres for discussion as has been done in the case of the West Midlands miscellaneous group.

The first group for consideration consists of Nos. 39, 39a, 40, 41. The soils on these areas are all derived from the Lower Greensand formation.

They are all sandy loams and the mechanical analyses show that they contain fairly large percentages of coarse sand and in addition approximately double these percentages of fine sand. The sum of the two fractions constitutes from 55 per cent. to 65 per cent. of the soil in each case.

At Centre 39 the percentage of clay shows a progressive increase to 30 in. depth and below that the soil contains sufficient clay to prevent excessively rapid downward drainage. Trees on this area have made excellent growth and do not suffer from leaf scorch.

At Centres 39a and 40 the soils to 30 in. are slightly coarser in texture than that at 39, and at 30 in. depth sandstone rock occurs. In both cases trees on these soils have scorched badly each season since planting, especially so at 40, where the trees are now in a stunted and useless condition.

At 41 the soil and subsoil are appreciably lighter than at the above centres, the samples containing approximately 70 per cent. of sand. The surface condition

persisted to a depth of 4 ft. where sampled. The condition of the young trees on this area indicates that many will fail entirely from severe leaf scorch.

Values for " available " potash and phosphoric acid are available only from two of these centres—Nos. 39, 41—and these suggest that the former is naturally low—0.0086 per cent. and 0.0095 per cent.—whilst the latter is of a much higher order—0.029 per cent., 0.036 per cent.—possibly as a result of phosphatic manuring. The soils contain small supplies of carbonate of lime—less than 1.0 per cent.—and are not acid.

Centres 42 and 42a occur in the same plantation. The mechanical analyses show that in both instances the soils are light sandy loams containing high percentages of fine sand. Here, however, scorch has been much less severe on the lighter area which would not be expected from former experience of this type of case. It is possible that the explanation of this apparent anomaly is provided by the results for " available " potash at the centres as the lighter area gives high values—0.0262 per cent., 0.0141 per cent.—while the heavier one gives only low ones—0.0099 per cent., 0.0047 per cent. " Available " phosphoric acid is high on both areas—surface soils 0.069 per cent., 0.063 per cent.—which is in keeping with previous manurial practice. Both soils contain high percentages of carbonate of lime—4.8 per cent., 4.6 per cent.

Centres 43 and 43a provide further examples of adjoining " scorch " and " scorch free " areas. The soil on the good area, 43, is a light fine sandy loam containing an appreciable percentage of clay at 30 in., while that on the bad area is much lighter and grades into a veritable sand bed at about 2 ft. During dry summer periods the soil on this latter area becomes thoroughly dried out when that on the better area is still nicely moist. In an adjoining grass orchard into which the soil conditions obtaining at 43a extend, cherry trees in the past have always failed to grow and have died out at an early age. The only chemical data available relate to calcium carbonate content and acidity. They show that the soils in both areas contain small supplies of calcium carbonate—surface soils 0.31 per cent., 0.66 per cent.

The areas 44 and 44a occur in adjoining plantations. The soil in 44, where apple trees have made excellent growth, is a fine sandy loam containing a good proportion of clay in the surface soil and becoming fairly stiff below 18 in. Over 44a the soil is much heavier than on 44, the mechanical analyses of the soils of the plot showing 10 per cent. less of fine sand in both surface and subsoil, and 5 per cent. and 10 per cent. more clay in the surface soil and subsoil respectively. The soil on this heavier area is very tough to sample and has a baked unweathered appearance. It is possible that this is another case in which the original surface soil has been eroded, leaving relatively unweathered and closely compacted material on the surface. This view is supported by the fact that the " Clay with

Flints " deposit over the chalk on the heavier area is only from 9 in. to 18 in. thick whilst on the lighter one it is several feet in thickness.

The only chemical data obtained for these two areas are those for carbonate of lime. Both soils contain ample supplies of this substance—surface soils 2.24 per cent. and 6.16 per cent. respectively.

Centre 45 is also located on the Clay with Flints formation. Soil and subsoil on this area are extremely flinty, flints constituting from 25 per cent. to 50 per cent. of the soil, whilst the matrix is a light sandy loam.

The value obtained for " available " potash in the surface soil is quite high —0.022 per cent.—but that for the subsoil sample is on the low side—0.0096 per cent. The values for " available " phosphoric acid—0.038 per cent., 0.0192 per cent.—suggest that good supplies of phosphates are present. Lime is present in both surface soil and subsoil—0.083 per cent., 0.071 per cent. It is of interest at this centre that the most unsatisfactory portion of it takes the shape of a narrow strip which is apparently continued into the adjoining cherry orchard and on which, as at centre 43a, attempts to establish cherry trees have been hitherto unsuccessful.

The last centre for consideration, at which the soils under 46 occur, appears to be a further case of leaf scorch resulting from poor drainage conditions. The site is a bad one, being located on a flat bottom between clay slopes.

Over the greater part of the area, surface soil and subsoil consist of close textured silty material into which it is very difficult to drive an auger. At various points over the area a stiff band of impervious clay as shown in 46a occurs. Apple trees on this area are miserable stunted specimens, which have always scorched badly. Around the outside of the area where trees have made average growth the soil was found to sample quite easily and to be nicely moist at a time when the soil on the bad area was hard and dry from the surface downwards, doubtless because of its impervious character.

The chemical data secured show low values for " available " potash—0.0061 per cent., 0.0040 per cent.—and phosphoric acid—0.0087 per cent., 0.0074 per cent.—in surface soil and subsoil, and a trace of carbonate of lime in all samples.

Discussion.

With the exception of one case, the soils of the leaf scorch centres considered above can be grouped together into three classes on the basis of texture, permeability to water and conditions of drainage. Such a basis appears to have considerable practical value in considering methods of controlling scorch. Under this grouping the class characters would be as under and the centres would fall into the various classes as shown in Table IX.

Class I. Surface soil and subsoil (where present) are open textured and conditions are such as to favour free drainage and relatively poor water supply during dry weather.

Class II. The surface soil is close-textured, generally a silty loam which may be poorly weathered and overlies a close-textured unweathered subsoil which is impervious to water. The soil may be subject to waterlogging during wet periods where the site is level and is liable to dry out quickly during periods of drought.

Class III. Surface soil and subsoil contain high percentages of clay and the drainage of the area is defective.

Centre 31 is the case which does not fit satisfactorily into any class. The problem of this centre is discussed further in Part IV.

TABLE IX.

Classification of Soils of the Leaf Scorch Centres.

Class.	Leaf Scorch Centres.
Class I.	8a, 10, 11, 12, 13d, 18a, 18c, 19a, 20a, 21, 22, 23, 24, 24a, 25, 26a, 33, 34, 35, 36, 37a, 38a, 39a, 40, 41, 42, 42a, 43a, 45.
Class II.	1, 2, 3, 4, 5, 6, 7, 8, 9, 12a, 12c, 13a, 13c, 14, 15, 16, 17, 30, 31a, 32, 44a, 46, 46a.
Class III.	27, 28, 29, 32.

From the above classification it would seem that the occurrence of leaf-scorch at the various centres considered is closely related to unsatisfactory conditions of water supply as all cases may be considered as liable to suffer from excess or deficiency of soil water.

That the two extreme conditions of soil water content are likely to be capable of producing leaf scorch by themselves in the field seems probable in view of certain results obtained by us in pot experiments. In experiments with apple trees (2) it has been demonstrated that leaf scorch can be produced by gradually drying out the soil in which the tree is growing and wetting the foliage after a certain stage of drying is reached. Also, with gooseberry bushes (page 250) growing in sand and receiving a complete nutrient solution capable of maintaining the foliage in healthy condition leaf scorch has been induced by waterlogging the root systems of the bushes after they had developed a set of healthy leaves.

Whilst waterlogging may be the only factor operative in producing scorch in certain wet areas, in cases of scorch on the light soils there is evidence to show

that drying out of the soil is not the only factor involved. In cases where drying out beyond a certain critical stage does occur this factor will be the dominant one, but such cases are likely to be few since such soils would be normally rejected by fruit growers as being obviously unsuited to fruit growing.

There are possibly two other factors which play important rôles in cases of leaf scorch on light soils, viz., potash supply and rate of spring growth.

Light soils almost invariably contain only poor supplies of potash and plants growing on them are generally likely to grow under conditions of low potash diets when potash manures are not applied. In pot experiments with various fruit trees in sand culture we have failed to control leaf scorch by ensuring an adequate supply of water to the sand medium in cases where potassium has been omitted from the nutrient solution given to the plants, whereas when sufficient potassium has been applied under the same conditions of moisture supply leaf scorch has not occurred. In this connection it has been shown by Mann (*loc. cit.*) that potassium exerts a controlling influence over the rate of transpiration under conditions of high temperatures and bright sunshine. It would thus appear that potassium produces a certain quality in the foliage of trees which enables them to resist certain factors conducive to the production of leaf scorch.

It will also be shown at a later stage that leaf scorch has been controlled by adequate potash manuring in certain of the light soil cases quoted above.

This last fact coupled with the observation that leaf scorch occurs on light soils in certain seasons prior to any serious drying out of the soil having occurred, shows that in many cases scorch does not result merely from excessive drying out of the soil.

It also seems possible that the rate of spring growth may be of importance to the problem of leaf scorch on light soils.* On such soils there is a tendency for trees and other plants to make very rapid growth during spring and early summer at which time the soils usually contain adequate supplies of water, whilst air temperatures are relatively low and the atmosphere fairly humid. Under such conditions trees are able to produce and support large leaf areas. As the season advances transpiration rates are increased while the water supply in the soil which is available to the plant is diminished. In this way trees may develop large foliage areas during the favourable spring period for which they are unable to provide adequate supplies of water during the hot summer period.

The possible factors conducive to leaf scorch in cases falling in Class II have already been enumerated on p. 269. No opportunity has occurred to date of examining the relative importance of the factors concerned at the centres coming within this class. There is evidence from two sources that potash manures may prove beneficial in such cases (1, 8).

* The results obtained in the pot experiments with apple Root Stocks, pp. 252 to 254, support this view.

In connection with the soil conditions in Class II. and also probably those in Class III., it is of interest to note that in the vine-growing areas on the Continent the diseased condition of the vine known as "flavescence," "rougeau" and "brunissure" occur in association with such conditions (7, 8, 9, 10). The symptoms in such cases are in many ways similar to those of leaf scorch and potash starvation in various plants and the conditions are most prevalent in periods of excessive wet or prolonged drought. One of these conditions—"brunissure"—has already been shown to be amenable to potash treatment (8).

It is possible in such cases that potash may exercise beneficial effects by aiding root development. We have shown in pot experiments with apple trees that trees receiving diets deficient in potassium often develop root systems relatively deficient in fine fibre (17), and in some cases in which slow rooting stocks have been used the trees have failed entirely to form any root systems. In water culture experiments with willow cuttings it has also been demonstrated that potassium is of importance in root development (16). In a field experiment with winter onions it was also found by the writer (18) that a dressing of sulphate of potash at the rate of 3 cwts. per acre resulted in greatly increased root formation.

It is not clear as yet how potassium acts in such cases and the subject is being further investigated.

Before concluding this section it is necessary to summarise the main points revealed by the chemical data and to refer to the chief features of the manurial practices at the centres considered.

The data for "available" potash in the surface soils from the scorch areas, where this has been determined, show that this is generally low. There are, however, eight cases in which the values are above 0.0150 per cent., and in three of these cases they exceed 0.020 per cent., viz.—29,42,45. It should be noted that of these three cases, at 29 scorch has resulted from waterlogging following an error in a drainage scheme on a soil not naturally liable to produce scorching and on 42 leaf scorch is only slight. Scorching is, however, very bad on 45.

It will be seen from the data presented for "available" potash in surface soils from scorch-free areas, that the values for these also may be low. There are five cases of such areas for which the values are below 0.01 per cent., viz., 13b, 18, 18b, 38 and 39. Mechanical analysis data are available for these areas and also for adjoining scorch areas and in every case the texture on the non-scorching area is superior to that in the scorching area when considered from the viewpoint of soil water conditions. The "available" potash found in the surface soil from the scorch area 18a is actually higher than that found in the surface sample from the adjoining scorch free area 18.

In view of the findings recorded in this paper relating to the importance of $\frac{\text{nitrogen}}{\text{potassium}}$ ratio and the action of potassium in controlling the transpiration rate it would appear that values obtained for "available" potash are of limited value. A striking example of the action of potash manures on a market garden crop in a case where "available" potash was as high as 0.0410 per cent. has been previously cited.

The values obtained for "available" phosphate in the surface soils are in most cases distinctly above the average for ordinary arable soils. There are only three scorch cases in which the values are low, being below 0.01 per cent., viz., 31, 38a, 46. In the majority of cases the values are above 0.02 per cent., and in six cases the amounts are greater than 0.05 per cent., which is a distinctly high value.

The data for calcium carbonate content and acidity show that leaf scorch may occur on non-acid soils containing varying amounts of calcium carbonate—a range from nil to 31.65 per cent. is recorded—or on acid soils—the highest "lime requirement" figure obtained being 0.49 per cent. There are, however, only eleven cases in which the surface soils are devoid of carbonate of lime and are acid in reaction, and of these cases there are only five in which the "lime requirement" value exceeds 0.20 per cent. Most of the surface soils contain small supplies of carbonate of lime—less than 1.0 per cent.—and are not acid in reaction.

The salient points of the information obtained regarding the manurial practices at the scorching centres are as follows:

1. In a few cases manures have never been applied.
2. Where manuring has been carried out it has been usual to apply "organic" manures containing nitrogen and phosphates, but either no potash or only a small percentage of potash, e.g. shoddy, bone manures, meat meal, fish meal.
3. Farmyard manure is generally not available in any quantity and in no case has it been used regularly.
4. Potash manures have never been applied regularly at any centre.
5. Lime has been frequently applied at certain centres and has not been used at others.

It is important to note with reference to this manurial information that leaf scorch has often developed at centres where regular manuring with fertilisers containing nitrogen and phosphates has been practised, whilst there are no cases where potash manuring has been regularly followed.

(to be continued.)

(Received February 27th, 1927.)

"REVERSION" IN BLACK CURRANTS.

II. ITS INCIDENCE AND SPREAD IN THE FIELD IN RELATION TO POSSIBLE CONTROL MEASURES.

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Introductory.

As soon as it became possible to recognise the symptoms of true Reversion with considerable certainty, methods for the eradication of the trouble both from the plantation and nursery remained to be evolved and tested.

In the first place an attempt was made to prevent the spread of reversion in the plantation by removing infected branches or bushes as soon as they appeared. Systematic methods of " roguing " were therefore adopted.

In the second place, nursery cuttings were selected only from bushes which had never shown symptoms of disease. In this way it was hoped to build up a reversion free stock.

The following pages describe the incidence of the disease both in plantation and nursery, and the measure of success attained in the control of the disease by the application of certain sanitary precautions.

Methods of Examination and Treatment.

When the main variety trials of Black Currants were established at East Malling in 1920, it was decided that not only the cropping of each individual bush should be recorded, but also the incidence of Big Bud and Reversion. However, experience had taught, during the previous classification period, that it was impossible to carry out successful cropping trials if disease were allowed to run its natural course.

Hence every bush was examined at least three times annually, early on in the blossoming period, again during the main growing season (between June and August), and finally about February, in order to keep a close watch upon disease. It was hoped during blossoming to detect " reversion " by means of the highly coloured flowers, and again to check this diagnosis by leaf characters in the growing season. The very partial success which followed from " roguing " by flower characters alone has been described elsewhere (1), the double examination making it possible to compare the earlier diagnosis from flowers with the later ones from leaf characters. Although it is possible, of course, that the writers, who carried out the roguing themselves, one walking up each side of the rows of bushes, may, here and there, have missed seeing cases of reversion, yet the fact remains that they identified double the number of cases from leaf

characters, in spite of the fact that this second roguing could not always be carried out at the time—June and July—most favourable for observing it.

The final examination was made about February, before the bushes were pruned, so that a complete record of the prevalence of big buds might also be made.

Each individual bush received certain marks according to its symptoms. The figures 1 to 5 represented the number of fifths (approximately) of the bush that were attacked by reversion. The letters " A " to " E " represented the degree of abnormality according to the scale described by Lees in his original paper entitled " A Method of Identifying Reversion in Black Currants " (2). " A " signified a shortage (then, less than *eight*) of uninnervated points, " B " less than five submain veins on *one* side of the central lobe of the leaf, " C " the earliest signs of a marked shortage of both, " D " a still more intense stage, and " E " an extreme manifestation.

It very soon became apparent, as has been pointed out elsewhere (1), that the " A " and " B " symptoms were in the vast majority of cases merely varietal characteristics since the whole French group would have to be considered as suspect, and that these manifestations by themselves did not develop into true cases of reversion. In the present paper, therefore, only " C " " D " and " E " symptoms are discussed.

The actual number of Big Buds was also counted, and the number of branches showing highly coloured flowers recorded.

The infected parts of all bushes which were marked as " 2 E " cases or less, were amputated after diagnosis. All bushes recorded as " 3 E " cases or over, were grubbed out, as being too severely infected to recover or give an economic crop. All big buds were removed at pruning. These individual bush records were continued for a period of seven years, and the following account summarises the details.

(A.) Incidence of Reversion in the Plantations.

In February, 1920, bushes of twenty-three named varieties of Black Currants were interplanted with apples in a plot designed for the purpose of studying varietal and cropping characteristics. There were seven full rows of currants consisting of seventy-three bushes each, five feet apart in the rows, and between them were seven rows of apples at fifteen feet square, interplanted with currants at 7 foot 6 inches. This gave a total population of 679 currant bushes. These, in the great majority of cases, had been raised in the Station's own Nursery and were planted out as one-year-old bushes. The cuttings, from which these bushes were derived, had been taken from bushes in plots which had already been under observation at the Station for the five previous years, and an attempt was made to select these cuttings from the best cropping plots and from healthy

bushes only, although no strict system of " roguing " or " trap nesting " was then practised, and none of the plots was completely free from " reversion."

It may be claimed with confidence that these one-year-old bushes represented generally the sort of material that a careful grower would plant. Their subsequent history with regard to the development and spread of " reversion " is therefore worth examination, although it should be emphasised once more that the primary object of the plot was to study varietal characteristics and yield, and therefore the spread of " reversion " and " big bud " had to be controlled by surgical methods. In addition, from 1922 onwards, the whole plot received the routine Lime Sulphur Spraying, which has been found here (3) to be a successful control for attacks of " big bud " of normal intensity.

It is first of all worth considering the progress of " reversion " upon the plot from year to year, and this can be seen from the following table :

TABLE I.

No. of Bushes showing Reversion each year.

Total Number of Bushes Planted 1920.	Total Number showing Reversion. Summer of	
679	1921	63
	1922	19
	1923	16
	1924	27
	1925	33
	1926	160
	Total " reverting "	308
	Balance healthy	371
Total 679		679

At first sight these figures do not appear very encouraging, especially after the preventive measures already described, but a closer examination of the details will place them in their true light.

In 1921 it became obvious that a number of bushes must actually have been at least in the incipient although non-detectable stages of reversion when planted out. In one particular instance, that of a complete row of seventy-three bushes of Victoria, no less than fifty-three of the bushes were so badly reverted the first season, that the whole row was eventually grubbed up in February, 1923. Although the previous history of the particular plot from which these cuttings were taken (in 1919) did not suggest a generally unhealthy condition at that time, yet within two years this whole plot failed owing to reversion, and there is little doubt that the trouble was latent in most of the cuttings when taken, and consequently in the young bushes when transplanted.

The other ten cases in 1921 were distributed here and there over the different varieties so as to suggest the accidental inclusion in the beds of cuttings of an occasional reverted or incipiently reverted shoot. The same may be said of the 1922 cases, and possibly even of those in 1923. At any rate they all gave the appearance of casual infections and were not very alarming.

When the actual positions of the fresh cases upon the plot were analysed from year to year during these first four years it was found that there is no evidence of spread from bush to neighbouring bush up or down the rows. This would confirm Lees' conclusion (4).

The following Table, which excludes the outside row of grubbed Victorias already referred to, takes into account the possibility of infection appearing during the two succeeding seasons, since as has been mentioned elsewhere (5), the " incubation period " of the trouble does not seem generally delayed over one, or, at most, two years.

Table II.

Fate of Bushes adjacent to Cases of Reversion.

Year.	Total No. of Cases of Reversion.	No. in which both adjacent bushes :—		No. in which one adjacent bush remained healthy and the other Reverted.
		became Reverted.	remained Healthy.	
1921	10	0	7	3
1922	17	0	13	4
1923	16	0	15	1
1924	27	7	8	12
Total	70	7	43	20

Thus whilst in 60 per cent. of these cases there is no evidence at all of the spread of the trouble through immediate proximity or contact, only 10 per cent. favour the possibility, and these cases all occur in 1924, when the probability of infection from outside the plot itself was greatly increased, as will be indicated later.

Infection from Outside Sources.

From 1924 onwards there is, however, a steady and ever-increasing rise in number of cases of reversion, and, when the position of these outbreaks was carefully studied, it became obvious that they had spread laterally across the plot from east to west. This is well illustrated in the following Table, which gives the percentage from row to row of bushes " reverting " in 1926.

TABLE III.

Spread of Reversion on Plot X.

	Row	Percentage of bushes reverting 1926.
From East	1	95
	2	75
	3	58
	4	40
	5	42
	6	35
	7	40
	8*	7
	9	26
	10	18
	11	9
	12	8
To West.	13	14

To a lesser extent the same sort of spread is apparent from the records made in 1924 and 1925.

The source of extraneous infection is not far to seek, for on the East, immediately adjacent to the plot under examination (Plot x) was an acre of bushes (Plot xi) devoted to a study of "big bud" and "reversion," many rows of which by the summer of 1925 had for experimental purposes been allowed to develop wholly or "5 E" reverted bushes, also infested with big bud mite.

If this source of extraneous infection needs any further confirmation it is to be found in the study of a black currant plantation immediately to the East of this "Big Bud" and "Reversion" plot. There is evidence of an exactly similar lateral spread of the trouble, but this time from West to East.

TABLE IV.

Spread of Reversion on Plot XI.

	Row	Percentage of Bushes reverting 1926.
From West	1	63
	2	55
	3	34
	4	33
	5	24
	6	17
	7	13
To East.	8	13

It is not proposed to discuss here how this infection was transmitted, but if the conclusions drawn elsewhere with regard to the part played by big bud mite are accepted (5), the cause would not be far to seek.

* This row happened to consist of a strain which has been consistently free from disease throughout the trials.

Thus, whilst there is no evidence of a general spread of infection from the 1921-24 centres of trouble within the plot, the evidence of its spread from the adjacent plot in 1925 and 1926 is overwhelming.

Indeed there is strong evidence, in the earlier years, of the success of the sanitary measures of cutting out and grubbing adopted on this plot, after which the effects of these measures are entirely overshadowed by an invasion from without. That Lime Sulphur spraying, which has been reported elsewhere (6) as indirectly reducing reversion, has been unable satisfactorily to stem this invasion from without, is also obvious, but this seems readily accounted for by the fact that there was this abnormally heavy unsprayed source of infection immediately adjacent, such as no wise grower would countenance.

Reversion, then, was not spreading upon the plot at a very alarming rate until this new contingency developed, and, even at the time of writing, of the 308 cases of "reversion" (excluding the grubbed row of Victorias already referred to) only seventy-nine have as yet been sufficiently severe to justify grubbing, and even the mildest "1 C" cases are included in the total.

According to the general tendency on the plot, it would, on the average, be another couple of years before the remaining cases would require grubbing. Although in some instances bushes have "reverted" completely in a single season, in the majority of cases the trouble has taken at least two years before it made the bush completely unprofitable. For instance, out of the 160 new cases of reversion in 1926, only ten were sufficiently bad to require grubbing then.

Owing to the number of varieties included on the plot, the varying experimental treatments and the unfortunate location, it would be unwise to attempt to draw any more detailed conclusions from this general survey, but two facts seem clearly to stand out, first, the general lack of evidence of spreading from individual local sources of trouble within the plot, and, secondly, the cumulative danger of an adjacent heavy source of infection from without. The cutting out or grubbing of cases of reversion within the plot undoubtedly removed the chief sources of potential Big Buds.

It is felt that no fair deductions can be drawn as to varietal susceptibility to "reversion," though the curious freedom of a particular strain of Baldwins in the very centre of the plot is not easily accounted for, especially as this variety has given no such indication of resistance upon other plots.

Control Measures in the Plantation.

There are, however, two aspects of the "reversion" question which are worth following more closely upon these bushes. It has already been stated that reverted branches were systematically cut out until the bushes became so badly affected that they had to be grubbed and replaced. What evidence does this plot afford as to the safety of replanting immediately in the place whence

reverted bushes have been grubbed ; and what evidence is there of the success of cutting out reverted branches in preventing the spread of the trouble on individual bushes ?

1. *Replacing Reverted Bushes by healthy ones in Young Plantations.*

In twenty-eight cases where reverted bushes had been grubbed, apparently healthy bushes were substituted, and their subsequent history recorded. Three of these replacements, believed to be healthy at the time of planting, reverted, two in the immediately succeeding season, and one after two years. The other twenty-five, however, have remained quite healthy. Since eight of these have now been in position for four years, and a further eleven for three seasons, the weight of evidence must be in favour of the three reverting bushes having become infected from some extraneous source, and there is no reason to suppose that risk is run by replanting where a reverted bush has stood. That this is worth doing for other considerations in the early life of the plantation is obvious.

2. *Cutting Out of Reverted Branches.*

Previous to the spring of 1926, some seventy bushes showed the symptoms of reversion originally only on a minor portion of the bush—e.g., on two-fifths or less. In all these cases the reverted portions were cut out immediately after diagnosis in July. The object was two-fold : (*a*) to attempt to check the spread of the trouble on the individual bush, and (*b*) to check its general spread in the plantation. That it fairly successfully accomplished the second end has already been suggested. The following figures show in what degree the former object was attained :

TABLE V.

Results of Cutting Out Diseased Branches from partially Reverted Bushes.

Total No. Reverted Bushes treated.	No. Grubbed the following year as reverted.	No. Grubbed within two years as reverted.	No. Surviving though in part affected.	No. apparently cured.
70	28	19	16	7

If, in the season following the cutting out, three-fifths or more of the remainder of the bush so treated showed symptoms it was immediately grubbed. Thus within two years forty-seven of the bushes had disappeared, despite the cutting out. In sixteen cases the spread of the trouble had been slow, but there is no direct proof that it would have been more rapid had the affected branches been left, since there were no "control" plants for comparison.

However, in the few cases where such branches were left, they invariably became serious centres of big bud infection.

Seven bushes out of seventy are definite instances in which the cutting out was evidently undertaken at a sufficiently early stage in the development of the disease to bring about a cure. In one of these cases the bush has so far remained healthy for four succeeding seasons, in another for three, and in four more for two. On the other hand, there have been instances on the plot of apparent recovery during one season, followed in the next or a subsequent one, by a renewed severe outbreak in the bush, necessitating ultimate grubbing.

Although these figures do not suggest that the cutting out can be confidently recommended as a sure remedy for individual cases, its general sanitary value remains.

That these roguing measures upon bushes destined to be used as sources of cuttings were reflected in the percentage of reverted bushes found in the Nursery will be apparent from what follows later.

B. THE INCIDENCE OF REVERSION IN THE NURSERY.

The fact that the symptoms of " Reversion " so insistently reappeared upon individual bushes from which all visible infections had been closely amputated, seemed to call for a more complete analysis of the individual bush, in order to discover whether the causative agent of reversion was really present in parts of the bush before symptoms of it became apparent. A series of experiments covering the whole field of propagation was therefore instituted.

BEHAVIOUR OF CUTTINGS FROM REVERTED BUSHES.

In February, 1922, some seventy Reverted Cuttings, showing different degrees of attack, were taken from four different varieties. All rooted, and they were examined during the growing seasons of 1922 and 1923. They all showed signs of Reversion in 1922, and, although some were not extreme cases when selected, all were marked as extreme (" 5 E ") cases in the summer of 1923.

As Controls, eighty-nine cuttings from healthy bushes of two varieties were planted adjacent to the reverted ones, and at the end of two years all of them were recorded as still healthy, though one, with a damaged top, showed " false " reversion. This experiment was repeated in 1924 on batches of 100 healthy and 100 reverted French cuttings planted in alternate pairs, and at the end of two seasons they fully confirmed the former results.

The writers have never grown a cutting from a completely reverted bush which has even appeared healthy temporarily ; on the other hand, it has not always been possible to reproduce in the young bush exactly the same manifestations (or presumably degree) of reversion that the cutting shows previous

to its severance from the parent bush. For instance, a number of cuttings were taken from bushes showing the typical " four veined " leaves and from others showing the extreme " oak leaf " type of foliage. Though all these cuttings subsequently showed " four veined " reversion, only one of those which had been originally selected as " oak leaved " showed this extreme manifestation of the trouble. The new growth merely produced typical four veined leaves.

A number of branches of " French," manifesting " highly coloured flowers," were also marked and subsequently used as cuttings. All those which struck developed typical symptoms of reversion during the two succeeding years (1922 and 1923).

Rooting Capacity of Reverted Cuttings.

Since it has been suggested from time to time that the rooting capacity of reverted cuttings is poorer than that of normal ones, it may be worth adding a note as to the experience in the Nursery at East Malling.

In 1922 cuttings from healthy bushes of " French " and " Blacksmith " rooted distinctly better than a similar series from reverted bushes. The trial was repeated in 1923 with fifty cuttings in each case of two other varieties, " Siberian " and " Ogdens " (both French Group). No differences in rooting were apparent.

Again, in 1924, a further batch of French cuttings was planted, and the reverted ones rooted slightly better than the healthy. If the three years' trials be taken together, approximately 81 per cent. of the healthy cuttings have rooted and 78 per cent. of the reverted. Probably the difference between these figures is not significant, since the number of cuttings involved in any one year was comparatively small.

Propagation from Partially Reverted Bushes.

This experiment in the series was designed both to answer a practical question and to shed some light upon the nature of the distribution of the trouble within the individual bush. Growers often ask, Is it safe to take cuttings from healthy portions of reverted bushes? The answer to this, as the figures will show, is emphatically *No*. For whilst a proportion—even a very large one, in certain circumstances—*may* produce healthy plants, there is at least a very grave risk that many, if not all, of the cuttings will produce reverted ones. Reversion apparently often travels further in a bush than can be recognised in any particular season.

The following figures speak for themselves and confirm the fact that the " causative agent " of Reversion may be present in parts of the bush even in a year when its blossom, leaves and fruit all appear perfectly normal.

Figure showing topmost branch of partially reverted bush typically diseased and barren.

TABLE VI.

Cuttings taken from Partially Reverted ("composite") Bushes, 1922.

Variety.	No. of Cuttings taken from apparently *Healthy* Portion of single Bush.	Subsequent condition after year.		No. of cuttings taken from *Reverted* Portion of same Bush.	Subsequent condition. after year.	
		Normal.	Reverted.		Normal.	Reverted.
Blacksmith	11	0	11	11	0	11
Baldwin	10 (6 died)	—	4	8 (all died)	—	—
French a.	15	11	4	15	0	15
French b.	12	8	4	12	0	12
French c.	14	1	13	34	0	34
Total Survivors	56	20	36	72	0	72

In another experiment cuttings were taken at random from a single bush of "Seabrook's," known to be approximately two-fifths reverted. These grew in the proportion of two reverted to four healthy.

It seems probable that the fate of cuttings taken from apparently healthy portions of otherwise reverted bushes depends, partly, upon the degree of severity of the trouble in the bush as a whole, and, partly, upon the relative proximity of the apparently healthy branches from which the healthy cuttings came to evidently reverted ones. A not altogether successful attempt was made to elucidate these points. A number of healthy cuttings from two partially reverted (composite) bushes was taken in the order of their actual position on the shoot—from the apex downwards—the object being to watch the behaviour of each cutting in relation to its nearness to the obviously diseased portion of the bush.

The two bushes (Nos. 53 and 66) from which the cuttings were taken, were both of the variety "French," but whilst No. 53 had approximately one-fifth of the bush extremely "reverted" (1E), No. 66 had one-fifth showing only the early stages of reversion (1C). All the apparently healthy cuttings from No. 53 became reverted, whilst all those from No. 66 remained healthy. Thus the result seems to strengthen the hypothesis that the degree of reversion on the diseased part may influence the future of the rest of the bush.

This sort of experiment is complicated by the fact that partially reverted bushes seem to exhibit two kinds of symptoms. Some bushes, under our conditions, so far a minority, show a single branch "reverting" from the top downwards (see Figure), as if infection had started at some one distinct point. Others show reversion apparently starting in the lower portions of the branch or stool and travelling upwards, as if the causative agent had been latent in the cutting itself, and it is to this class of bush that an attempt has been made to confine this particular series of experiments.

PROPAGATION FROM BUSHES OF KNOWN HISTORY IN THE "ROGUED" PLANTATION.

The above experiences in the Nursery led the writers to the conclusion that the only method of securing reversion-free stocks would be the raising of races from bushes, the individual histories of which were known. The material growing upon the plot already described at the beginning of this paper served the purpose, and affords some suggestive figures.

The improvement rapidly brought about by following this system is well illustrated in a particular strain of "French Black" (H1)—the best on the Station in 1919. In the following year a plot of seventy-three bushes of that strain was established, the cuttings for these having been taken from apparently healthy bushes in the parent plot. However, 4 per cent. of them turned out to be reverted, and of the 150 cuttings taken indiscriminately from these seventy-three young bushes 8 per cent. were diseased. This illustrates the rapid "degeneration" of an infected strain. Meanwhile the parent plot had "degenerated" even more rapidly, for in 1920, although care was exercised to avoid apparent cases of reversion, out of some 600 cuttings taken from the apparently healthy bushes, 30 per cent. gave reverted bushes.

It was then decided to carry out the roguing of the new plot of seventy-three bushes much more systematically, and the following results were obtained:

In 1923 out of 523 cuttings there were none reverted.

In 1924 out of 2,000 cuttings there was 1 reverted.

In 1925 out of 1,200 cuttings there were none reverted.

In 1926 out of 2,300 cuttings there were 13 reverted.

The cases of reversion which did still appear can be accounted for, in the main, by the fact that here and there a parent bush, apparently quite healthy in the summer of one season, exhibited in the following spring all the symptoms of extreme reversion. On all the varieties on the plot, during the five years under review, there have been sixteen instances in which bushes showed perfectly normal flowers and foliage in one summer and yet by the following spring they were diagnosed as 3E, 4E, or 5E cases—and no less than seven of these occurred in 1926. There have been many more less severe cases recorded. For instance, in the five chief varieties there have been, out of a total of 365 bushes, 104 which appeared normal one summer and exhibited undoubted reversion early the next, but again the vast majority (eighty-two) of these cases occurred in 1925 and 1926. The risk of an occurrence of this kind undoubtedly increases with the age of the individual bush, and that of the whole plantation, and it is therefore to be recommended that, wherever possible, only bushes of from two to five years be selected as the source of cuttings. It has already been explained that the particular plantation from which these cuttings were taken, became seriously

infected during 1925 and 1926 with reversion from an extraneous source, viz., an adjacent badly reverted plantation, and therefore however carefully individual bushes might be " rogued," the risk of the sudden appearance of new cases must rapidly increase. In such cases, the reversion did not always show itself in the cuttings during the first season, so that however carefully yearling bushes are " rogued " there is a risk that some latent reversion may remain unrecognised.

The records of the cutting beds of other varieties similarly raised from the same plot confirm the general value of roguing. They also emphasise the increase of risk as the plantation gets older. They are given in the following table :

TABLE VII.

Percentage of Reversion in Yearling Cuttings from Rogued Bushes.

Planted Spring.	1923.		1924.		1925.		1926.	
	No. of Bushes.	% Reverted.	No. of Bushes.	% Reverted.	No. of Bushes.	% Reverted.	No. of Bushes.	% Reverted.
Boskoop	730	1.4	1600	0	1200	0	1600	0.6
Seabrook	1047	0.4	2000	0	1200	0	2500	0.3
Goliath	1022	3.0	1300	0.2	1200	0	1800	0.8
Baldwin	684	0.2	750	0	1200	0	1500	0.1

Similar figures for other strains and varieties bear out the general conclusion as to the value of careful roguing. One batch of such cuttings, consisting of 910 Baldwins, was planted out permanently at the Station in 1923, and is now, therefore, three years old. They remained perfectly healthy for two years, though in 1926 three cases of reversion appeared, and there is strong evidence that the infection came from an outside source.

THE ESTABLISHMENT OF " CLONE " LINES OF DIFFERENT VARIETIES.

Although the difficulties of establishing lines completely free from infection were realised to be very great on a Research Station where reverted material had always to be kept on hand for experimental purposes, one further attempt was made to " select out " reversion altogether.

In the spring of 1924, single parent bushes of the five main groups were selected for their previous good record of health and cropping. These were cut to within a few inches of the ground, and all the " wood " removed was used for establishing clone lines of currants. The oldest bushes from these single parents —there were approximately 120 of each planted out—have now made four years' growth. Careful examination has, with a single exception,* failed to reveal any Reversion to date.

* Reference to the Nursery Records shows that these particular cuttings were raised dangerously near to a series of reversion experiments.

Three further batches of cuttings within the same clones approximately 500 of each in all, have made one year's growth and have also failed to reveal a single case of Reversion in the Nursery rows. Another 2,000 yearlings, the clone lines of some of the sub-types of black currant, also appear entirely free from reversion in the Nursery.

But whilst in the space of three years it has been possible to raise certain apparently reversion-free strains in quantity, the history of other of these clone lines must serve as a warning against too great optimism. Thus, in three varieties, namely, "Hoogendyk's Seedling," "Black Mammoth," and "Blacksmith," reverted yearlings were discovered in the Nursery beds in 1926, although the parent stools were apparently healthy in 1925. The original stools—which unfortunately had to remain in situ on Plot X in order to save time—were immediately examined and found to have developed reversion in varying degrees. On the other hand, out of the thousands of young bushes so raised, there have as yet only been five cases of breakdown that cannot be traced to the rapid reverting of the parent, and must therefore be the result of some extraneous infection.

Since under such adverse circumstances, it has been possible to raise strains so comparatively free from the trouble, the results must be considered encouraging to those wishing to build up reversion-free stocks.

The writers are once again indebted to the Staff of the Ministry's Pathological Laboratory, Harpenden, for many helpful suggestions and criticisms of which they have made full use in this paper.

SUMMARY.

1. Detailed observations upon a plot of 679 Black Currant bushes which had been lime sulphur sprayed annually, and had surgical methods applied also, offer no definite evidence of the spread of reversion from bush to bush within the plot during the first four years.
2. A rapid spread of the disease subsequently can be traced to an exceptionally heavy centre of reversion and big bud in close proximity.
3. Under these latter conditions, the single spring Lime Sulphur Spraying has proved insufficient to stem the tide of such continuous heavy infection.
4. The intensity of the disease and its progress have been very variable from bush to bush. In some cases the apparent development is astonishingly rapid, in others comparatively slow.
5. The frequent replanting of healthy bushes in the place of diseased ones which have been removed does not suggest that infection is carried through the soil.

6. When minor portions of bushes have shown disease, surgical methods have been applied, and though in exceptional instances the removal of reverted portions has resulted in at least a temporary "cure," in the vast majority of cases, the disease has not been materially checked within the individual bush, thereby.
7. On the other hand, the cutting away of diseased parts and the removal of wholly infected bushes are to be urged as sanitary measures.
8. The incidence of reversion in the cutting bed has been studied. The danger of taking cuttings even from apparently healthy portions of diseased bushes is demonstrated. On the other hand, in no instance has a healthy bush resulted from the planting of a reverted cutting.
9. The promising results of applying "roguing" methods (as detailed in Part I. of this paper), to the parent bushes and subsequent cutting beds are set forth after four years' trial.

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(Received March 15th, 1927.)

STUDIES IN THE PHYSIOLOGY OF FRUIT TREES.

II. THE EFFECTS OF RINGING, DOUBLE RINGING AND DIS-BUDDING UPON THE STARCH CONTENT AND CAMBIAL ACTIVITY OF TWO-YEAR-OLD APPLE SHOOTS.

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Introduction.

In the previous part of this study (25) the normal seasonal changes in starch content and cambial activity were presented. The present part deals with single-ringing experiments carried out in 1925, and with double ringing and dis-budding experiments carried out in 1926. The recent discussions upon the problem of translocation have used as a criterion the presence or absence of starch above, between, or below rings. Realising that such discussions are only possible upon a basis of an adequate knowledge of the normal seasonal changes in starch content, this general study was undertaken. The observations recorded in the work upon the physiological anatomy of ringing (24) were extended to cover double ringing and dis-budding experiments. These latter experiments were carried out in 1926 upon the same trees as were used to determine the normal changes in starch content and cambial activity. (25.) In view of the great variation in seasons, the times of the recorded changes may vary from year to year. The order of the changes may also vary, but in general the order set out in Part I. of this study may be regarded as normal for young apple trees growing under cultivated fruit plantation conditions in the West of England.

The Effect of Ringing at Different Dates upon Starch Content and Cambial Activity in Two-Year-Old Apple Shoots.

(*a*) *Ringing before Bud-break*, 1925.

These data were obtained during the investigation previously recorded (24) and details as to the method employed may be obtained from that paper. Two-year-old apple shoots were ringed on February 7th, 1925, and subsequently gathered for examination at suitable dates. The descriptions of starch content in these ringing experiments apply only to the 20.0 cms. above and below the rings, unless otherwise stated. It is important to remember this, because it was shown earlier that the starch distribution on any one date may not be the same in branches of varying ages. When these rings were made (February, 1925) starch was abundant in the medullary rays, wood parenchyma,

and cortical cells, but was almost absent from the phloem. No perceptible change either in amount or distribution of this starch was observed until March 17th. Starch then began gradually to disappear from the xylem tissues under and in the immediate vicinity of the ring. This gradual disappearance continued until May 5th when a rapid starch disappearance began in the xylem tissues above the ring. By May 20th starch was absent for at least 20.0 cms. above the rings, but at 2.5 cms. below them there was no perceptible starch disappearance except from the phloem. Thus, the rapid and complete sweep out of starch in spring was temporarily restricted to the parts *above* the ring. By May 20th when the parts above the ring were depleted of starch content, the flowering season was almost over, a considerable development of foliage leaves had taken place, and the lateral buds immediately below the rings had begun to elongate into extension shoots.

By June 5th a small amount of the characteristic viscous substance such as described in the previous paper (24) had developed in the medullary ray cells under the ring. Very little of this wound gum had, however, escaped into the vessels. On May 26th there was no differentiation of new vessels for at least 10.0 cms. either above or below the rings, but on June 5th a row of new vessels was present at 5.0 cms. above the rings. Thus in these ringed two-year-old branches new xylem differentiation above the rings was subsequent to the disappearance of starch from the xylem tissues. About June 8th—i.e., a few days after the initiation of xylem formation immediately above the ring—a reversal in starch content above and below the rings set in. Starch began to accumulate in the xylem above the rings and to disappear from it below them. The accumulation above the rings was rapid, so that within fourteen days it was fairly abundant in all the tissues. The starch disappearance below the rings was not so rapid as it had been above them, and in some cases it was not carried to completion. Differentiation of new xylem did not begin in the 5.0 cms. below the rings until the end of June, which was subsequent to the extension growth of buds immediately below the rings.

(*b*) *Ringing on May 12th*, 1925.

On this date the cambium was "swollen" and the rings of cortex and phloem were easily separated from the woody cylinder. Starch was absent from the phloem, almost absent from the cortex, and had mostly disappeared from the xylem tissues, over the whole of the two-year-old branches. Within ten days after ringing the starch disappearance was complete above the rings, whereas below them starch tended if anything to accumulate. The starch re-deposition set in above the rings about June 10th, and the disappearance from below them about June 20th. Thus, in rings made on May 12th, 1925, the reversal in starch content was not coincident above and below the rings, as it was in those made

before bud-break. This is no doubt associated with the fact that lateral buds immediately below the rings were longer in breaking on the shoots ringed in May. A further point also emerges, namely that xylem differentiation below the May rings was delayed even longer than in those made before bud-break. This may be correlated with the partial depletion of food reserves at the time of ringing, and with the "swollen" condition of the cambium.

Ringing on June 16th.

On this date the trees were all in full leaf. Starch was abundant in the cortex, fairly abundant in the xylem tissues, and almost absent from the phloem. The immediate effect of ringing in this case was the disappearance of starch from the xylem tissues *under* the ring. The parts above the rings rapidly accumulated starch without any preliminary depletion, but below them there was no accumulation until the end of July. In covered rings made after the beginning of June callus developed from *both* edges, and a fusion of this tissue took place across the rings. This re-establishment of organic continuity across the rings resulted in an equal starch storage above and below them, whereas when there was no healing over the starch storage below the rings was much less than it was above them.

Thus, in rings made on June 16th there was no preliminary sweep out of starch from above the rings, but a rapid accumulation of it above them, and a much slower one below. The starch storage below the rings was more rapid, and more abundant in those cases where an organic continuity of the tissues over the ring was established, or where several vigorous laterals developed below the rings early in the season.

Ringing in July and August.

These branches showed a rapid accumulation of starch above the rings. Considerable amounts of fatty substances also accumulated in the younger medullary ray cells above the rings. The amount of this substance continued to increase until the end of September. Ringing after the end of August had no appreciable effect upon starch storage, the amounts above and below the rings showing no difference at the end of September. The buds immediately below the rings made in August and early September swelled considerably, but never passed beyond this initial stage of growth during the current year.

These ringing experiments bring out the following points: (*a*) ringing effectively restricted the early spring starch disappearance to the parts above the ring, until such time as buds immediately below the rings began to grow out, when starch disappearance began below the rings. (*b*) In ringed branches the starch disappearance was markedly in advance of new xylem formation, particularly above the rings. (*c*) Where rings healed over there was an equal

TABLE I.

Showing the Effects of Double Ringing upon the Starch Content and Cambial Activity in Apple Shoots.

RINGS NOT COVERED OVER.

Date of Examination and Tissue.	*Not Disbudded Between Rings.*			*Disbudded Between Rings.*		
	At 5.0 cms. Above Rings.	At Mid-way Between Rings.	At 5.0 cms. Below Rings.	At 5.0 cms. Above Rings.	At Mid-way Between Rings.	At 5.0 cms. Below Rings.
March 19th, 1926.	*Buds swelling.*					
Pith	Abundant.					
Xylem	,,					
Phloem	Fair amount.					
Cortex	Abundant.					
Cambium	*SLIGHTLY SWOLLEN*					
April 30th, 1926.		*The more vigorous buds broken.*				
Pith	Absent	Abundant	Abundant	Absent	Abundant	Abundant
Xylem	,,	Fair amount	Fair amount	,,	,,	Fair amount
Phloem	,,	Absent	Absent	,,	,,	Small amount
Cortex	Small amount	Small amount	Fair amount	Fair amount	,,	Fair amount
Cambium	*Some cells vacuolated*	*Swollen*	*Swollen*	*Some cells vacuolated*	*Slightly contracted*	*Swollen*
May 12th, 1926.						
Pith	Absent	Absent	Fair amount	Absent	Abundant	Small amount
Xylem	,,	,,	Small amount	,,	,,	Absent
Phloem	,,	,,	Absent	,,	Fairly abundant	,,
Cortex	Small amount	,,	Fair amount	,,	Abundant	,,
Cambium	1 *row of vessels* *Not yet lignified*	*Some vacuolated cells*	*Some vacuolated cells*	1 *row of vessels* *Not yet lignified*	*Only slightly swollen*	*Some vacuolated cells*
May 26th, 1926.						
Pith	Small amount	Small amount	Fairly abundant	Small amount	Abundant	Fairly abundant
Xylem	,,	Absent	Small amount	,,	,,	Small amount
Phloem	Absent	,,	Absent	Absent	Fairly abundant	Absent
Cortex	Fair amount	Fair amount	Fairly abundant	Fair amount	Abundant	Fairly abundant
Cambium	4 *rows of vessels*	1 *row of vessels*	1 *row of vessels*	4 *rows of vessels*	*Slightly swollen*	2 *rows of vessels*
June 16th, 1926.						
Pith	Very abundant	Abundant	Abundant	Very abundant	Abundant	Fair amount
Xylem	Fairly abundant	Fairly abundant	,,	,,	,,	,,
Phloem	Fairly abundant	Small amount	Very small amount	Abundant	Small amount	Small amount
Cortex	Very abundant	Abundant	Abundant	Very abundant	Abundant	Abundant
Cambium	10-14 *rows of vessels*	10-12 *rows of vessels*	9-10 *rows of vessels*	10-11 *rows of vessels*	*Swollen*	8-9 *rows of vessels*
July 29th, 1926.						
Pith	Very abundant	Very abundant	Very abundant	Very abundant	Small amount	Abundant
Xylem	,,	,,	Abundant	,,	Fair amount	,,
Phloem	,,	Abundant	,,	,,	Absent	,,
Cortex	,,	Very abundant	,,	,,	Fair amount	Very abundant
Cambium	20-24 *rows of vessels*	16-20 *rows of vessels*	16-20 *rows of vessels*	23-26 *rows of vessels*	*Cells vacuolating*	18-20 *rows of vessels*
August 16th, 1926.						
Pith	Very abundant	Very abundant	Very abundant	Very abundant	Absent	Very abundant
Xylem	,,	,,	,,	,,	Almost absent	Abundant
Phloem	,,	Abundant	Abundant	,,	Absent	,,
Cortex	,,	Very abundant	Very abundant	,,	Almost absent	,,
Cambium	24-26 *rows of vessels* 1 *only not lignified*	18-22 *rows of vessels* 2 *not lignified*	18-20 *rows of vessels* 3-5 *not lignified*	23-26 *rows of vessels* 2 *not lignified*	*Cells all vacuolated*	20-22 *rows of vessels* 2 *not lignified*
September 14th, 1926.	*Same as for August 16th except cambial activity has ceased and xylem lignified up to cambium.*					

starch re-deposition above and below the point of ringing. Where the rings did not heal over there was a marked difference in the amount of starch which accumulated above and below the rings.

DOUBLE RINGING EXPERIMENTS, 1926.

On March 19th, 1926, a number of two-year-old apple branches were selected. Some were marked as controls, the others were double ringed, the rings being about 1.0 cm. wide and 10.0 cms. apart. The branches were ringed about mid-way between the 1923-24 and 1924-25 annual leaf scars, and two or three well developed buds were left between the rings. Half the double ringed branches were then disbudded between the rings. In some cases the rings were covered over with adhesive surgical tape. Unfortunately owing to loss of material from unforeseen causes there was insufficient available to carry out the desired number of examinations. The main results of these double ringing experiments are extracted and summarised in Table II.

On March 19th, 1926, starch was abundant in the pith, xylem and cortex, and fairly abundant in the phloem. By April 30th it had disappeared from the parts above the upper rings, and from the phloem below the lower ones irrespective of the treatment between them. It had also disappeared from the phloem between the not-disbudded rings, but not from between the disbudded ones. During the period April 30th to May 12th, starch remained absent above the rings. On the latter date starch was also absent from between the non-disbudded rings, but no disappearance had taken place between the disbudded rings. On May 26th starch had begun to re-appear in the cortex of the parts above the upper rings in both cases, and to a less extent between the not-disbudded rings. By this date there was a perceptible *disappearance* of starch from the phloem between the disbudded rings. On June 16th starch was abundant in all the parts above the upper rings and fairly abundant in the parts between the not-disbudded rings, and the disappearance from between the disbudded ones was further advanced, but far from being complete. In all cases of non-disbudded rings the two or three lateral buds left between the rings invariably developed into growth. They mostly developed into rosettes of small leaves, but quite a number of the upper buds developed into short extension shoots. Normally very few if any of these buds would have developed into extension shoots. The buds immediately below the lower rings invariably developed into extension shoots. It appears, therefore, that even where two complete rings are made upon the same branch, the physiological responses around the upper ring are of the same nature as those around the lower rings but are less intense.

It is essential at this point to distinguish between the results in covered and uncovered rings. In covered rings callus growth was abundant from the upper and fairly abundant from the lower edges of both rings where the parts between

them were not disbudded. Where they were disbudded the amount of callus was much less from the lower edges of the upper rings and the upper edges of the lower ones. In the uncovered rings there was an abundance of the excrescent type of callus developed from the upper edges of both rings not disbudded, and from the upper edges of the upper disbudded rings, whereas in the latter case the amount from the upper edge of the lower ring was almost negligible. Callus rarely developed from the lower edges of uncovered rings. By June 16th the callus of the covered rings had almost invariably fused over the upper and in some cases over the lower ring, but there was no fusion over uncovered rings, not even at the end of the season. The effect of this healing over was most noticeable in those branches disbudded between the rings. As already stated the parts between disbudded rings showed very little starch disappearance until after June 16th, but immediately subsequent to the upper rings healing over starch rapidly and completely disappeared from between the disbudded rings, and cambial activity began. Thus, on June 16th, starch was fairly abundant and there was no new xylem formed between unhealed disbudded rings but starch was absent from between healed disbudded rings, and there were several rows of vessels. Unfortunately material was not available to determine whether it was the healing over of the upper, or lower, or both rings, which resulted in the activity. The limited number of observations suggests that the healing over of the upper ring alone can give it.

Branches examined on June 25th and July 9th were found packed with starch above the rings, and on the latter date cambial activity had ceased above the rings. Examinations on September 14th showed that starch had completely disappeared from between the uncovered disbudded rings, but there was no xylem formation between them. Most of the cambial cells had vacuolated and were very similar in appearance to the cortical tissues. In all cases starch was very abundant above the upper rings, and fairly abundant below the lower ones. In the uncovered not-disbudded rings starch was abundant between the rings and cambial activity had been almost normal, whereas between the uncovered disbudded rings starch was absent—despite its presence above the upper and below the lower ring—and there had been no formation of new xylem. Thus the healing over of the rings caused the parts between the disbudded rings to behave in a normal manner as regards starch disappearance and cambial activity.

On March 19th the cambium was slightly swollen over the whole tree above ground. It is significant that xylem differentiation was delayed between the not-disbudded rings for at least fourteen days as compared with normal branches and the parts above the rings. In disbudded rings, of course, it did not begin unless the rings healed over or dormant buds were allowed to develop. The amount of xylem formed between not-disbudded rings was consistently less

TABLE II.

Showing the Effects of Disbudding One-year-old Apple Shoots upon the Starch Content and Cambial Activity.

Date of Examination and Tissue.	Control Shoot.	Shoot disbudded except Terminal.	Shoot completely Disbudded.
March 19th, 1926.			
Pith	Abundant		
Xylem	,,		
Phloem	Fair amount		
Cortex	Abundant		
Cambium	*Slightly Swollen*		
April 27th, 1926.	Terminal Buds Broken.		
Pith	Abundant	Abundant	Very abundant
Xylem	Small amount	Small amount	Abundant
Phloem	Absent	Absent	Fairly abundant
Cortex	,,	,,	Abundant
Cambium	1 *row of vessels*	*Swollen*	*Slightly swollen*
May 7th, 1926.			
Pith	Absent	Absent	Abundant
Xylem	,,	,,	,,
Phloem	,,	,,	Fair amount
Cortex	,,	,,	Abundant
Cambium	3 *rows of vessels*	1 *row of vessels*	*Slightly swollen*
May 31st, 1926.			
Pith	Absent.	Absent	Fairly abundant
Xylem	,,	,,	,,
Phloem	,,	,,	Almost absent
Cortex	Small amount	,,	Abundant
Cambium	10 *rows of vessels*	4 *rows of vessels*	*Slightly swollen*
June 14th, 1926.			
Pith	Small amount	Small amount	Fair amount
Xylem	Fair amount	Fair amount	,,
Phloem	Small amount	Small amount	Almost absent
Cortex	Abundant	Abundant	Fair amount
Cambium	11-12 *rows of vessels*	9-10 *rows of vessels*	*Cells vacuolating*
July 11th, 1926.			
Pith	Fair amount	Fair amount	Fair amount
Xylem	,,	,,	Abundant
Phloem	Small amount	Absent	,,
Cortex	Fairly abundant	Fairly abundant	Small amount
Cambium	16-18 *rows of vessels*	12 *rows of vessels*	*Cells vacuolating*
August 16th, 1926.			
Pith	Abundant	Fairly abundant	Fair amount
Xylem	,,	,,	Abundant
Phloem	Small amount	Small amount	Fair amount
Cortex	Abundant	Fairly abundant	Absent
Cambium	20-25 *rows of vessels*	18 *rows of vessels*	*Cells vacuolated*
September 14th, 1926.			
Pith	Very abundant	Very abundant	Abundant
Xylem	,,	,,	,,
Phloem	Fairly abundant	Abundant	,,
Cortex	Very abundant	Very abundant	,,
Cambium	*Passing into Winter Condition*		*Vacuolated*

than that above the rings. It is clear from these observations that rings of phloem and cortex removed from branches retarded the initiation of xylem formation below them, and that in the absence of developing buds between rings there was no xylem formation, but the healing over of the rings was followed almost at once by cambial activity. It was repeatedly observed that there was a distinct lack of proportion between the amount of tissue healed over at a ring and the physiological result produced. Where only one-sixth of the total circumference was in continuity over a ring the parts between the rings behaved as though there was no ring at all. Similar observations have been previously recorded by Curtis.

Disbudding Experiments, 1926.

In this series of examinations a number of one-year-old (i.e., 1925 extension growths) shoots were selected on March 19th, 1926. A third of them was marked as controls, a third was disbudded except the terminal bud, and the remaining third was completely disbudded. Owing to the development of small dormant lateral buds on some of the material, the amount available for examination was less than had been anticipated. The observations are summarised in Table II.

When this experiment was started starch was abundant in the pith, xylem and cortex, and fairly abundant in the phloem of control materials. By the end of April it had disappeared from the cortex and phloem, and almost from the xylem of both control and disbudded-except-terminal shoots, but there was no disappearance from the completely disbudded shoots. Starch remained absent from the control and disbudded-except-terminal shoots until the end of May, then it began to re-appear in small amounts in the cortex. By this time starch had disappeared from the phloem of the completely disbudded shoots, but not from the xylem or cortex. The examinations of June 14th, 26th, and July 11th showed an increasing amount of starch in the control and disbudded-except-terminal shoots, and a further but incomplete *disappearance* from the completely disbudded shoots. A completely disbudded shoot which had developed a lateral outgrowth at about half-way up was examined on July 29th. Transverse sections taken at 2.0 cms. below this outgrowth showed a complete absence of starch and several rows of new xylem. The latter extended only half-way round the stem, and were directly below the outgrowth. At 10.0 cm. below this outgrowth there was less new xylem than at 1.0 cm., and at 20.0 cm. there was only one row of vessels. At 1.0 cm. above the outgrowth there was no cambial activity and starch was abundant in all the tissues except the phloem. Examinations of similar shoots in August and September revealed the same phenomena. Thus, the disbudded-except-terminal shoots behaved in a normal manner as regards the starch cycle and cambial activity. The completely

disbudded shoots, however, showed but little starch disappearance and no cambial activity during the season in which they were disbudded. Where they developed lateral outgrowths they lost all their starch below but not above them, and also developed new xylem below but not above them.

On July 11th an interesting case of cambial activity was observed in a completely disbudded shoot. About half-way down the shoot a small triangular piece of cortex and phloem had been torn out, leaving a small amount of the woody cylinder exposed. Transverse sections of the stem were taken at the point of wounding. From each edge of the wound cambial activity had developed about one-third of the way round the stem, and several rows of *abnormal* unlignified xylem elements had been produced. At 5.0 cms. below this wound several rows of *normal* xylem tissue were differentiated on the side below this wound. There was no cambial activity at 1.0 cm. above the wound. Starch was absent below the wound, but abundant above it. In this case therefore, a wound had produced in a completely disbudded shoot the same results as were produced by the development of lateral outgrowths in the other disbudded shoots.

DISCUSSION.

It is hoped in a future communication under this general title to discuss the relation of the present experimental results to practical horticulture. The present discussion, therefore, will be restricted to a tentative consideration of the more strictly physiological problems involved.

The first point of interest is the establishment of a well-defined starch disappearance in winter. It was shown earlier that a similar starch disappearance has been previously recorded by several workers. In some cases it has been recorded as a complete starch disappearance from woody stems, but in the present investigations upon apple trees, it occurred only in the phloem. Such starch disappearances in winter have almost invariably been attributed to the direct effect of low winter temperatures, but this is by no means critically established. Russow (20) and D'arbaumont (6) both regard it as being largely independent of immediate climatic conditions. Chandler (3) also points out that it has been reported from parts of America which have a three months' continuous winter frost and from locations which rarely if ever have freezing temperatures. Price (19) shows that on January 9th, when the maximum temperature was 42° F., starch was absent from the phloem tissues of the one to nine-year-old branches of apple trees, whereas on March 9th, with a maximum temperature of 10° F. lower than in January, starch was abundant in all the tissues. Mitra (16) has recorded the mean temperature over the period May to April, 1919-20, and the seasonal changes in carbohydrates in apple spurs and one-year-old seedling apple trees, over the same period. The curves for both starch and total carbohydrate show a marked fall, beginning on January 1st and

reaching a low point on January 15th. This is followed by a marked rise to a maximum on February 15th, and this secondary maximum is followed by a very low minimum at the time of rapid spring growth. If the curves of temperature be plotted upon the same graph then it is clear that the low temperature period (below freezing point) began on November 1st with a very low point (12° F.) during the period December 1st to January 1st. This marked separation in point of time between the very low temperatures and the marked starch disappearance does not suggest a close direct relationship between the two. It is suggested that this temporary starch disappearance in winter, is part of a larger general physiological activity occurring in woody stems during the leafless period. Thus Mitra (16) found that total sugars increased during winter up to a maximum in January and February. The data of Kraybill and others (13) show a similar condition. It may be that this winter starch disappearance is associated with the ending of the rest-period of the buds. (Rest period here being used to denote that period during which buds will not develop into normal shoots when given such temperature and water conditions which would normally give abundant growth.) It is well-known that buds pass out of this so-called rest period sometime before they show visible signs of growth in spring. Hodgson (10), after an extensive examination of a large number of species concluded that the majority of them end their rest period early in January. A further discussion of this interesting point must await the accumulation of more knowledge regarding the physiology of woody stems and roots during the so-called dormant period, which in temperate climates is so coincident with the leafless period.

There appears to be an influence of developing buds upon starch disappearance and cambial activity in spring, which is difficult to understand. Jost (11 and 12) found that disbudded seedling beans gave little or no radial growth of the stele although the stems increased in diameter by the growth of both pith and cortical cells. He also found that the removal of the terminal buds of Pinus sylvestris was followed by almost complete inhibition of radial growth. Lutz (15) showed that disbudding beech and pine trees before bud break inhibited cambial activity and starch disappearance from these trees. Starch disappearance, however, took place the following December. Nordlinger (17) records essentially the same thing. Reich (21) states quite definitely that in Chili there was no radial growth in woody species unless there was bud development. The above evidence and that given earlier in the present work suggests that there is some close relationship between the presence of developing buds on stems and the initiation of radial growth within them. It was shown in the double ringing experiments that there was no radial growth between the rings unless (*a*) there were developing buds present, or (*b*) the rings healed over. In the absence of buds between the rings the cambium and xylem regions between them behaved

like the disbudded trees of Lutz and Nordlinger, and the disbudded shoots described earlier in this paper. A lack of continuity in the tissues external to the xylem cylinder was followed by all the phenomena of physiological isolation in the regions between the rings, notwithstanding the fact that the parts of the stem above and below this region were behaving normally. It was also shown that the subsequent development of small buds on otherwise disbudded stems was accompanied by an amount of xylem formation which was proportional to the vigour of such a bud, but a starch disappearance which was not proportional to bud vigour. In all cases the starch disappearance went to completion in the whole stem region below such buds, but they exerted little or no effect above them. Thus, in these cases at least, the amount of xylem formation was not proportional to the amount of reserve food substances originally present in the stems, but to some factor in the developing bud. Neither was the initiation of cambial activity dependent upon the presence of reserve foods, but primarily upon bud development. This relation of buds to cambial activity and the initiation of the growth cycle in the woody parts of perennial plants was also noticed by Howard (9), for he concludes that "the secret of the rest period lies in the buds rather than in the cambium, roots, or any of the tissues of trunk or branches."

The above contention that in normal stems the initiation of xylem formation in spring is in some way closely connected with the proximity of developing buds, was further strengthened by some observations made upon apple scions heeled into the ground in the spring of 1926. These were examined about the end of July. Most of them were dead but several were still alive and had developed small buds with two or three very small leaves. Starch was completely absent from these shoots, but the amount of xylem formed in them was directly related in amount and position to the size and position of these developing buds. That other factors may cause the initiation of xylem formation in disbudded stems was shown by the single case of wounding reported earlier in this paper. It appears that cambial activity depends for its initiation upon some sort of stimulus. At present, however, we are ignorant of the nature of this stimulus beyond the indication that it is associated with the developing buds. The continued activity of the cambium *is* dependent upon food supply, as is abundantly shown by all the defoliation experiments, but at present it is difficult to determine from the chemical analyses at our disposal those changes in food concentration—if any—which are operative in determining when a cambium shall *start* into active growth in Spring. The weight of evidence suggests a relation between the initiation of cambial activity and the presence of unfolding leaves or developing buds. It may be ultimately shown that these latter induce marked changes in the more soluble carbohydrates and nitrogen compounds which in turn become the effective agents.

Pearsall and Priestley (18) suggest that the hydrogen ion concentration of the fluids moving in the plant tissues is important. Both Abbott (1) and Mitra (16) show that there are definite seasonal fluctuations in the hydrogen ion concentration of the extract of plant tissues, particularly the tips of apple and peach trees. It is conceivable, therefore, that developing buds, which are centres of high respiration and metabolic activity, may also be centres of disturbances in hydrogen-ion concentrations. In any case, the established basipetal order of events both as regards starch disappearance and the initiation of cambial activity in spring, suggests that the apical buds occupy an important position. Further development and discussion of this interesting problem must await the development of more satisfactory methods of determining the hydrogen ion concentration in sections of plant tissues.

The well-marked starch disappearance during the early maximum growth period in spring, is equally complex. It represents a using up of reserve food substances. It cannot be too strongly emphasised that such a starch disappearance is not a question of simple hydrolysis. It is in some ways related to the usage of the starch reserves from a germinating seed, but is markedly different in that the cells of these woody tissues continue to live, and may repeat this storage and depletion cycle many times in the course of their lives, whereas in developing seeds, or potato tubers, the cells die after having given up their starch content. Nor does it appear to be a direct function of the water columns in the xylem vessels, such as Sinott (23) has suggested, for Gardner (7) points out that the starch reserves of the xylem parenchyma and medullary ray cells of Robinia are depleted annually in spring and re-stored in autumn. Except for the few outer rows of vessels the xylem tissues of Robinia are completely blocked with tylosis so that it is impossible to force water through them even under high pressures. The evidence of Auchter (2) and Knowlton (14) indicates that radial movement in xylem tissues is comparatively slow, so that it would appear that this starch disappearance in Robinia is part of a larger physiological response. The occurrence of starch grains in a living cell is such as to preclude any direct reaction to the external conditions. Considering the nature of enzyme action it is difficult to picture Coville's (4) explanation of the starch disappearance as a result of cold. The plant cell is always bathed in a watery solution of salts, organic acids, and other organic compounds, a fluid which undoubtedly may show considerable local concentrations in particular substances, but which is nevertheless a fluid common to all the plant cell walls. Changes in external conditions such as light, temperature, and water supply produce changes in the metabolism of cells or tissues. These changes are reflected in the end products of metabolism and changes in equilibrium conditions. It becomes important, therefore, to examine carefully both microchemically and macrochemically the tissues of woody plants

during winter and early spring in order to detect changes which could be regarded as causally related to bud break and changes in the metabolic direction of the living cells of woody stems.

The chronological relation between bud break, cambial activity and starch disappearance thus becomes important. In 1926, at Long Ashton, Bristol, England, this relationship was as follows. With increasing mean temperatures in spring, the buds began to swell. This swelling was prior to any observed changes in the starch content of the woody stem, excepting the starch disappearance from the phloem in early February. This beginning of growth in the buds was accompanied, but more frequently followed almost immediately by the swelling of the cambial tissue over the whole tree above ground. The cambium became swollen, turgid and translucent, as contrasted with a somewhat shrunken, opaque appearance during winter. Following this bud and cambial swelling starch disappeared from the phloem over the one-to-ten-year-old branches. It also began to disappear from the cortex, beginning in the cells adjoining the phloem first of all and then progressively towards the epidermis. Within about fourteen days after the cambium swelling starch began to disappear from the xylem tissues immediately below the terminal buds. This starch disappearance from the xylem proceeded basipetally and was followed downwards by the initiation of new xylem formation. Thus, it appears that xylem formation is usually preceded by a somewhat incomplete starch disappearance, but the latter is preceeded by growth changes in the terminal buds and by changes in the cambium tissue. These observations only extend over one year, and in view of the fact that there is indication that these time relationships may be somewhat different in non-flowering as against flower-bearing shoots, and highly vegetative as against weakly vegetative stems, they stand in need of further confirmation and expansion. Curtis is of the opinion that the starch disappears because of the removal of the sugars by the developing buds and cambium. The starch disappearance in January, its early disappearance from the phloem in spring, and the beginning of its disappearance from the xylem in advance of rapid xylem formation suggests that the process *begins* before there are conditions which may be regarded as having a large demand upon sugars. It will be remembered that in the double rings which healed over the starch disappearance *began immediately* and was carried to completion before cambial activity had become at all vigorous between such rings. The continuity of the phloem and cambial tissues appears to be a necessary condition for the downward progression of the starch disappearance and initiation of cambial activity in spring. In normal stems the starch disappears from the xylem tissues, and the initiation of cambial activity takes place progressively downwards and is in some way closely associated with tissue continuity and developing buds.

It is possible that bud break, starch disappearance and cambial activity are all related to some common causal factor. This, however, might be difficult to reconcile with the growing body of evidence that the conditions which favour elongation growth are different from those that favour radial growth. The former appears favoured by conditions that result in a relatively large supply of available nitrogen and water and a low carbohydrate supply, whereas the latter appears favoured by a relatively higher carbohydrate to a lower nitrogen supply. Thus, ringing usually results in increased radial growth above the rings as compared with below them (8 and 12), but a reduced elongation growth, whereas shading often results in excessive elongation growth but reduced radial growth. In analysing such ringing, shading, and defoliating data it should not be forgotten that the *time* of ringing is very important. Thus both Curtis (5) and Harvey (8) report that when ringing was done early in the year it produced the effects recorded above, but if done later in season, it increased elongation growth. It is shown by Roberts (22) that radial growth is much greater in the " off " year than in the " on " year in biennially bearing trees. The available evidence all goes to show that the proportion of carbohydrate substances is much higher in the " off " year than in the " on " year.

This discussion should at least have some reference to the problem of translocation. The double ringed not-disbudded shoots show a normal cycle of events above, between and below the rings. When these rings are compared with those which were disbudded between the rings, several points of interest emerge. There was no starch disappearance from between the disbudded rings (at least until very late in the season) and no xylem formation, although both these activities took place above and below the rings. The region between such rings behaved as though it was physiologically isolated.

This lack of starch disappearance may be taken as an indication of the function of the phloem in translocation. Chemical analyses alone will settle this point. At present, however, in view of the other evidence presented in this paper, the lack of physiological activity in such a region of the stem may be due to non-continuity of the cambium or phloem or both, a continuity which may be distinct from any problem of mass food movement. The constancy of the basipetal tendency in the spring and autumn growth activities is indicative of some fundamental physiological law operative in the woody shoots of perennial plants. This tendency brings us at once into close contact with such practical problems in horticulture as the vegetative propagation of woody species, budding, grafting and pruning.

It is hoped in a future communication to discuss further the bearing of this work upon the practical problems of horticulture. Perennial plants such as our fruit trees are living units, the summation of all the internal responses made by them to the whole of the environmental conditions that have played upon them.

Responses to environment in the first place are all changes in metabolism. These changes are sooner or later expressed in external features such as varying habits of growth. Variations in growth habit are indicative of variations in metabolism. Profitable horticulture eventually resolves itself into growing trees that bear fruit, and our cultural practice, pruning, and fertilisation is designed to this end. As we come to understand more fully the physiology of fruit trees, it will be possible to develop cultural practice and procedure upon a more scientific basis. The urgent problem in horticulture is to know *how* it is that our trees grow so differently. For instance, how is it that the varieties of apple which normally spur up well in one part of England produce so much bare wood at Long Ashton. We must know more of the relationship of root growth to the seasonal top growth and *vice versa* ; and how climatic conditions can influence both ; and how these in turn affect blossom bud formation and the setting of fruit once blossom buds have been produced. The present study forms some sort of basis upon which such problems may be attacked, for in the last resort, they are all problems in metabolism. Such studies must concern themselves more and more with internal responses, and these must be correlated with their corresponding external growth expressions. It is along such lines, by a closer correlation of internal changes to external responses that we can hope for an increasing ability to mould growth into those channels which are most desirable to our purposes.

SUMMARY AND CONCLUSIONS.

(1) The 1925 ringing experiments were confined to the 20.0 cms. above and below the rings made on two-year-old branches. They showed (*a*) That during early May there was a marked sweep out of starch from the parts above the rings, but that the rings effectively prevented this starch disappearance from progressing further down the branches. (*b*) Xylem formation began earlier above the rings than it did below them. (*c*) About June 8th, starch began to accumulate on the stem parts above the rings and to disappear from those parts below them. This latter starch disappearance was associated with the development of lateral outgrowths below the point of ringing. (*d*) Xylem formation began below the rings during the period of starch disappearance there. (*e*) The starch accumulation above the rings was much in advance of the same event in normal unringed branches. (*f*) The date of ringing markedly altered the responses produced. (*g*) There was a large difference in the amount of starch accumulated in the parts above and below those rings which did not heal over. It was extremely abundant above the rings and the amount below them was proportional to the size and number of the lateral outgrowths that developed below the point of ringing. Where rings healed over the amounts were equal.

(2) The 1926 double ringing experiments have revealed the following significant facts. (*a*) There were differences in the time of the occurrence of the

dominant phases in the starch cycle and cambial activity above the rings as compared with unringed branches. (*b*) The starch cycle and cambial activity followed a normal sequence between the not-disbudded-rings, but the events were delayed ten days as compared with normal shoots. (*c*) There was no starch disappearance from between the disbudded rings until the middle of July. At this time starch was accumulating above the upper rings. (*d*) There was no xylem formation between disbudded rings, but the cambium cells passed over into a vacuolated condition. (*e*) The healing over of the rings resulted in starch disappearance and xylem formation between the disbudded rings and a subsequent starch re-deposition. (*f*) The physiological response produced between the disbudded rings which healed over was not proportional to the *amount* of tissue continuity that was established.

(3) The disbudding of one-year-old shoots showed (*a*) that disbudded-except-terminal shoots were almost normal both as regards starch cycle and cambial activity. (*b*) Completely disbudded shoots showed little or no starch disappearance until very late in the season. By September the cambium had lost its meristematic condition but there was no xylem formation. (*c*) Subsequent bud development upon completely disbudded shoots invariably resulted in starch disappearance and xylem formation *below* the origin of such buds, but not *above* them. The amount of xylem formation in such cases was proportional to the vigour of the bud, but the starch disappearance was carried to completion irrespective of their vigour. This xylem was localised to the part directly below the buds. (*d*) In one case a wound made accidentally upon a disbudded shoot caused a xylem formation and starch disappearance in all points similar to that resulting from the development of lateral buds.

(4) A temporary disappearance of starch—particularly from the phloem—during winter is established. This starch re-appeared prior to the beginning of spring growth. It is suggested that this temporary starch disappearance is not so directly associated with immediate temperature conditions as has been previously supposed. It is possibly related to the ending of the " rest " period of the buds.

(5) Developing buds—particularly terminal ones—appear to play an important rôle in the processes that lead to the *initiation* of cambial activity and starch disappearance in woody stems in spring.

(6) The beginning of spring growth may be associated with changes in the hydrogen ion concentrations of the cell sap and the fluids bathing the cell walls during winter. There is evidence to show that definite seasonal fluctuations occur in the hydrogen ion concentration of the expressed sap of woody stems.

(7) These experiments indicate that the starch disappearance in spring begins in the xylem before cambial activity is very far advanced and that cambial

activity ceases after the heavy starch accumulation in Autumn. There is more experimental basis for the latter than for the former of these statements. Both, however, stand in need of further substantiation.

(8) The slowing down of elongation growth was accompanied by a marked starch accumulation in the stems. This began in the terminal regions and worked in a basipetal direction.

(9) Phloem and cambial continuity appear to be essential for the co-ordinated and continuous physiological activity in woody stems. Double ringing stems produced the phenomenon of physiological isolation in the parts between the rings unless there were buds or shoots present between the rings.

(10) The marked basipetal tendencies in Spring and in Autumn become important factors in any consideration of the problems involved in the vegetative propagation of hard wood cuttings, grafting, budding, and pruning.

(11) The tree is a unit. Its growth responses faithfully portray its internal conditions. As we understand more fully the correlation of internal conditions to external growth responses, we shall have more power to induce that kind of growth which is most suitable for our purposes.

I wish to acknowledge the receipt of a Ministry of Agriculture Research Scholarship while carrying out this work.

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A SURVEY OF SOME EMULSION PROBLEMS CONFRONTING THE SPRAYER.

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Spray substances used for the purpose of checking insect pests and plant diseases must possess certain characteristics: in the first place, they must be toxic to the insect or fungus without being harmful, in any great degree, to the plant. Secondly, they should be capable of inexpensive and simple dilution to give sprays which can be easily and efficiently applied. Finally, they should be comparable in price with other remedies used for the same purpose. The present paper constitutes, in the main, a *résumé* of the emulsion problems confronting the sprayer, special attention being paid to these points.

During the last few years, the use of mineral oils as insecticidal, ovicidal and cleansing washes in winter has become very widespread. In Europe, coal tar fractions are mostly in favour; on the American continent, partly because of the great petroleum industry, petroleum fractions are mainly used.

It is characteristic of mineral oils that they are insoluble in water, the cheapest, most abundant, and least harmful diluting medium. As "naked" oils would be harmful to trees, besides being expensive, the question arises as to how they may be diluted; one obvious method is to make an emulsion.

An emulsion is a liquid system consisting of tiny particles of one liquid suspended in another liquid; and, if the emulsion is to be so concentrated as to possess insecticidal value, an emulsifying agent or emulsifier—which is adsorbed round the particles of the dispersed liquid to form a rigid layer which prevents coalescence—must be used.

A moment's consideration will lead to the notion that *two types* of emulsions are possible; in one case, droplets of oil may be dispersed in water to give an *oil-in-water* type of emulsion, and, in the other, droplets of water may be surrounded by oil to give a *water-in-oil* emulsion. The failure to realise this fact has proved serious in many cases, *for the type necessary to the sprayer is the oil-in-water;* this alone is capable of dilution with water, for water constitutes the continuous medium surrounding the oil particles. The water-in-oil type, similarly, can be "diluted" only with oil, as oil is the continuous external medium; such dilution, of course, means the application of large amounts of "naked" oil, and the very object of making the emulsion is defeated.

Another method of diluting these oils is to make them soluble in water by the addition of some third substance. If one adds pyridine, totally miscible

with benzene or water separately (the last two compounds being practically immiscible), to a mixture of benzene and water, the two clear layers obtained will both be found, on analysis, to contain some of all three liquids (1), *i.e.*, the addition of the pyridine has increased the solubility of the water in the benzene, and *vice-versa*; by varying the relative amounts of the three liquids present, the two layers can be made to give one. Now mineral oils, similarly, are not very soluble in dilute soap solutions (2), but the addition of a phenol such as cresol, soluble to some extent in soap solutions and oils, causes the solubility of the oils to increase. The optimum methods of preparation and amount of the phenol necessary have been thoroughly investigated previously (3), and it has been shown that though oil solutions of petroleum fractions can be obtained of sufficient concentration for winter spraying, this is not so in the case of coal tar fractions such as creosote and anthracene oils. It should be pointed out, however, that the use of solutions such as these with very hard waters—unless previously softened by soap—is impracticable, as the balance of the constituents is altered by precipitation of insoluble soaps.

To return to emulsions, sprayers will have noticed that the materials offered to them for dilution are in two forms: the first is a "stock" (3) or "free" (4) emulsion; the second a "miscible oil" (3).

A proprietary stock emulsion is an actual emulsion of the oil-in-water type containing so much oil and emulsifier as to be of a non-creaming, pasty or semi-solid consistency (5). A "miscible oil" is a solution of emulsifier in the oil, a liquid of clear consistency resulting; the actual emulsion is got from this on mixing with water. It will be apparent that, though some water is necessarily present as the continuous medium of a stock emulsion, none need be present in a "miscible oil," the latter being, therefore, more economical in transport; on the other hand, a stock emulsion is usually easily diluted, but to make dilute emulsions from "miscible oils" often demands great care and skill, the question as to how to dilute—water to oil, or oil to water—being one problem.

The actual manufacture of stock emulsions containing much oil involves many interesting problems: it has been found that addition of the oil to the emulsifying medium in small amounts at a time, together with intermittent shaking or pumping—a process which is followed in making mayonnaise—greatly lessen the labour (6); in the case of soapy emulsifiers, a high temperature appears desirable (3).

In making stock emulsions, a knowledge of the efficiency of individual emulsifying agents for given oils is imperative; little work has been done on this aspect of emulsification (7), and it is impossible at present to state that a certain emulsifier will cause easier emulsification of a certain oil than all other emulsifiers.

Emulsifiers can, however, be divided into two broad classes, members of one tending to give oil-in-water emulsions, members of the other the opposite type. Holmes (8), goes so far as to draw up two lists of emulsifiers giving emulsions of opposite types, but the work of Seifriz (9) and Woodman (10) has disproved the rigidity of these lists; in the light of recent research, it seems that no prediction of type can be general, but that a systematic survey of type formed with all emulsifiers for any given oil is necessary, strict attention being paid to pH, partition problems, method of preparation, relative volumes of oil and aqueous phases, *etc.*

One of the most serious problems confronting the sprayer in all countries is that of hard water; water is said to be *hard* when it is found difficult to raise a more or less permament lather with soap. This is because of the presence in hard waters of calcium and magnesium chlorides, sulphates and bicarbonates, and sodium chloride. The bicarbonates, because precipitated as insoluble carbonates on boiling the water, are said to induce *temporary* hardness; the calcium and magnesium chlorides and sulphates cause *permanent* hardness, chemical treatment being necessary to eliminate them; whilst common salt causes what is known as *pseudo*-hardness.*

On adding soaps to hard waters, the soaps are decomposed by the calcium and magnesium salts to give insoluble curdy precipitates of calcium and magnesium soaps. All the calcium and magnesium salts present in the hard water must be so precipitated before the soap begins to lower surface tension, cause wetting and spreading, lather, or emulsify. That this is a serious factor will be perceived when it is stated that Wisbech water used for spraying required about 20 lbs. of soap per 100 gallons to soften merely (11), before the soap assumed its normal functions of wetter, spreader and emulsifier.

Even if hard water is expensively softened by soap previous to its use for emulsification or emulsion-dilution, unless filtered or decanted, there still remains another objection to its use, and that is the tendency of the calcium and magnesium soaps formed to promote the undesirable water-in-oil type of emulsion. This tendency is often seen when mixing up stock emulsions and "miscible oils" with hard water in practice, soaps or resinates being the emulsifiers; the insoluble soaps formed give large quantities of water-in-oil emulsion, which, being incapable of mixture with water, forms suspended globules and sticks to the sides of the containing vessel.†

* This hardness is due to the insolubility of soap in water containing sodium chloride. The so-called "marine soaps," obtained by saponification of the cocoa-nut oil group of oils, possess the remarkable property of needing large amounts of salt to throw them out of aqueous solution (*vide* Lewkowitsch, *Oils, Fats and Waxes*, 1908, 2, 738). These soaps are suggested by the author as of possible use in emulsification when the natural water supply is briny.

† Sometimes previous addition of sodium carbonate or hydroxide to the water will tend to give the desired oil-in-water type (12).

Though soaps and resinates are probably the most efficient wetters and spreaders and the best emulsifiers for incorporation with "miscible oils," other substances are equally efficient for making stock emulsions. The use of such emulsifiers as sodium and calcium caseinates, gelatine (glue or size), saponin, the gums, dextrin, rubber latex, lipoid substances such as lecithin and egg-yolk, Irish moss, agar-agar, *etc.*, can be recommended as emulsifiers for use with hard waters, because of non-reactivity* with dissolved salts.† Even then, the presence of dissolved salts might be found to exert an effect on the type of emulsion formed.

In addition to the facts that an emulsifier may promote the wrong type of emulsion, and that hard water may cause inversion to the wrong type, the sprayer or manufacturer of stock emulsions must surmount other difficulties. One of these is the influence of the "phase volume ratio" on the type formed. Thus Clayton (13), in discussing the manufacture of margarine, has emphasised that the relative volumes of the milk and oils used, and hence the order of addition, may determine the type formed ; Seifriz (9) has shown that altering the phase volume ratio of Diamond paraffin oil and aqueous casein may cause inversion ; and Woodman (10) has proved that alteration in the relative proportions of cresylic acid and aqueous gelatine determines the type of emulsion formed. As a stock emulsion contains large quantities of oil, the emulsion in certain cases may be water-in-oil ; though it is probable that the great quantity of water necessary to dilute this stock emulsion to the spraying strength might invert the stock to the desired oil-in-water type, this dilution, complicated by an inversion, would be exceedingly difficult.

Mechanical treatment and method of handling may also influence the type formed, even when the phase volume ratio remains unaltered. Thus Seifriz (9) has shown that standing some emulsions for twenty minutes with subsequent re-shaking may cause inversion. Woodman (10) has also obtained this result,

* The writer has known cases where caseinates, size, etc., have had to be used in conjunction with "miscible oils" to form emulsions in hard water ; this is defeating the purpose of a "miscible oil," for obviously the original emulsifier contained in the spray is taking no part in emulsification, but is merely re-acting with the salts causing hardness. The emulsification is due to the second non-reactive emulsifier, and a stock emulsion is really being formed and diluted down ; thus it would be more logical, and much cheaper, to use the non-reactive emusifier alone. In other words, the manufacturer of proprietary oil sprays should sell two classes : (1) a "miscible oil" for use with softer waters, and, (2) the toxic oil used in the manufacture of that "miscible oil" made up as a stock emulsion with a non-reactive emulsifier for very hard waters.

† Very hard waters will always be unsatisfactory for spraying. It is probable that much injury and scorch put down to the toxic constituent of the spray, is in reality due to the dissolved salts in the water, and that the water alone would cause comparable injury. Softening by soap means, of course, replacing in solution calcium and magnesium salts by sodium and potassium salts, which, being also soluble, are liable to cause injury, whilst the use of non-reactive wetters, spreaders and emulsifiers does not interfere with the original calcium and magnesium salts present, and hence scorching must be as serious as with the untreated water.

and has shown, further, that, in the case of a system containing 50 per cent. by volume of cresylic acid (or of a pure cresol), the emulsifying medium being aqueous gelatine, the *actual mode of shaking* the two liquids together determines the type formed ; in this last-named system, the water-in-cresylic acid is the stable type of emulsion formed under *all* conditions of preparation and for *all* phase volume ratios, the reverse and desirable type tending to break and separate out immediately. The use of emulsions of cresylic acid, therefore, is apt to be dangerous to trees.*

From a brief survey of the foregoing difficulties confronting the sprayer, it would seem that the use of emulsions is fraught with great danger ; happily, there are some few preparations of coal tar and petroleum fractions which, under normal conditions and with moderately soft water, have proved efficient. Further research might tend to make the use of emulsions much more certain, safe and efficient under any given set of conditions.

SUMMARY.

A brief survey of the difficulties which will be encountered in the manufacture and application to trees of the so-called " miscible oils " and " stock " emulsions of coal tar and petroleum fractions has been made, the material for the survey having been gathered from various " pure " scientific papers on emulsions.

It has been shown that two types of emulsion, oil-in-water, and water-in-oil, are often possible when the materials for making an emulsion are shaken together. Of these two types, the oil-in-water one, which alone represents true dilution of the toxic but phytocidal oil constituent of the spray emulsion, and which can be diluted by any further amount of water, is that absolutely necessary to the sprayer.

Evidence has been given demonstrating the fact that the relative proportions of the oil and the aqueous emulsifying medium shaken together, and that the mechanical treatment given during preparation, may determine the type formed. Re-shaking an emulsion may sometimes also cause inversion to the undesirable type.

The hardness of water and its influence on emulsion type has been explained, methods and suggestions for overcoming complications arising from the necessary use of hard water being given.

* Since doing this work, similar results have been obtained by using potassium oleate (a soft soap), in place of gelatine ; the unstable cresylic acid-in-water emulsion is, as Lees (14) has shown, very toxic to eggs (of *A. pomi*), but would be dangerous to trees, without doubt.

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THE INTERNATIONAL HORTICULTURAL CONGRESS OF 1927.

WIEN (Vienna) was selected as the venue of the International Horticultural Congress for 1927, for during that year the Austrian Horticultural Society was celebrating its Hundredth Anniversary. The place proved convenient, for nearly four hundred members joined the Congress, coming from places as far away as Canada, America, Egypt and Japan.

The Austrian Horticultural Society had made excellent arrangements and secured much assistance from their Government, the Authorities of the University, and of the City of Vienna.

The Congress took place in the buildings of the University, and the Professor of Botany—Professor W. Ettstein—became the President-elect. The members of the Congress met at the University during the mornings, when discussions took place on subjects of international interest. In the afternoons excursions were made to see places of horticultural interest.

The points raised in the discussions fall naturally under different headings and do not lend themselves well for grouping into an article. The following gives in a few words some thoughts on the subjects raised:

HORTICULTURAL NOMENCLATURE.

Professor Suringar, of Wageningen, Holland, gave an account of the systems used for naming plants in the various countries. He gave instances where the same plant was mentioned by different names in catalogues of England, Holland and America, and of instances where the same name was shared by two plants. He thought that this lack of agreement was causing confusion which might easily be obviated if only the several nations would come to an agreement on the names to be used.

Camillo Schneider, Berlin, suggested that the following books might serve as a basis. "Standard Plant Names," "The Standard Cyclopedia of Horticulture," edited by Bailey, and for dendrological matters A. Rehders new "Manual of Cultivated Trees and Shrubs."

Professor Tanaka of Japan gave an outline of the Vienna Code of Botanical Nomenclature (1905) and of the Brussels Code of Horticultural Nomenclature (1910), and suggested that if these findings were followed up an agreed nomenclature could be settled.

Dr. Rendle (England) suggested that as a result of the meeting and discussions that had taken place in Vienna (1905), in Brussels (1910) and in America (1926), many of the difficulties were disappearing. He thought that if the Horticulturists and Botanists were to co-operate together at the next Congress in 1930 a suitable international method might be agreed.

The Congress appointed a Committee representative of the countries interested and working under the Chairmanship of Dr. Rendle, to study further the problems involved and to make definite proposals to the Congress when next held.

International Agreement on Colours.

Dr. Krüger, Dresden, suggested that horticulturists needed a colour scheme representing all the colours which occur in nature and easily expressed in popular languages of all nations.

The method of measuring colours had been improved and facilitated through the use of the graduated photo metre by Pulfrich, with the supplementary apparatus of Klinger. The system of Wm. Ostwald's, he said, which was employed to a large extent in the textile industry of Germany, had already been adopted by some horticulturalists—as, for example, the seed catalogue of Ernst Benary of Erfurt, and the Atlas of coloured roses of the Society of Friends of Roses E.V.

Philippe Rivoire, Lyons, instanced the repertoire of colours of the French Society of Chrysanthemumists based on the works of Chevreuil and de Dauthenay in collaboration with Payne (France), Leithlin (Germany) and Severi (Italy).

The Congress set up a Commiteee to study and report on the colour schemes in further detail.

International Agreement on the Granting of Certificates of Valuation. Starting an International Book of Novelties.

Mr. T. Macoun, of Canada, suggested that the only possible satisfactory international or even national system of Plant Registration was one maintained and directed by the Government staff. Trials should be conducted and distinct varieties of a really high class, registered so as to guide purchasers. The Canada Seeds Act of 1823 gives the Government power to prevent the introduction of unregistered varieties and he suggested that a similar plan be adopted in other countries.

Philippe Rivoire, of Lyons, explained that the National Society of Horticulture of France has introduced certificates of " Superior Merit " which are granted to meritorious varieties after a three-years' test. Friedrich Werner, of Germany, said that the German National Horticultural Association have a scheme for testing novelties :

(*a*) at the nurseries with the possible result of being classed as " remarkable," and

(*b*) at selected testing stations with the possible result of obtaining a certificate of value.

Fr. Kralochwjle, of Vienna, was in favour of an international committee to draw up the conditions under which certificates could be given. The Congress set up a Committee to consider and report further on this matter.

FRUIT TREES.

(*a*) Inquiry into the conditions of flowering and fertility of fruit trees.

(*b*) International agreement on the nursing of fruit trees, e.g., height of trunk, stocks.

Dr. Magnus, of Berlin, traced the sterility of fruit trees to the following facts :

(1) That many plants are unfertile themselves. Fruit trees propagated by shoots must be regarded as one plant which is multiple self-sterile.

(2) That many species of fruits are hydrids—which as a class are often self-sterile.

(3) That the physiological changes caused by the domestication of the fruit has had a bad influence on the sexual cells.

Dr. Kobel, of Switzerland, said that his researches into the process of fecundation and its abnormalities had led to important results in practice. The examination of the germinative faculty of the pollen has proved that there are a good many types of partial sterility of the pollen in apples and pears and it is caused by the composition of the cellular node and the number of chromosomes.

The partial sterility of the pollen with stone-fruits is caused by abnormal condition of the chromosomes only in the case of the mahalab cherry ; it is certain that with the species of stone fruits the germinative faculty and the germinative power of the pollen depend largely on the influence of nutrition.

Fr. Langenecher (C.S.R.) thought that the Congress should decide on the best form of fruit trees for commercial plantations and for private gardens ; agree on the stocks to be used, and issue a pronouncement to guide nurserymen. O. Schindler, of Pillnez, stressed the importance of dealing with the " stock " question and also for the Congress to lay down standards of quality for young fruit trees.

Juroslav Vesely Molitorov stressed the importance of having further studies made into the stock question. He thought that the Government Experimental Stations should breed constant stocks and also test the stocks normally issued by the trade in much the same way as " seed " are tested by the Governments at the present time.

Development of the present International Committee for Horticultural Congresses into an International Bureau.

Dr. Sirks, of Wageningen, Holland, explained that the existing International Committee consisted of delegates nominated by the Governments of Austria, Belgium, Germany, Great Britain, Hungary, The Netherlands, Norway, Poland and Switzerland, and that its functions were limited to the fixing of the date and venue of (and making arrangements for) International Congresses. He suggested that an International Bureau of Horticulture was necessary to form a continuous bond between the horticulturists in the various countries. He thought the Bureau should work in association with the " Federation Horticole Professionelle Internationale " the International Agricultural Institute at Rome, and the Commission Internationale d'Agriculture at Paris.

H. V. Taylor (London) put forward a case for the need for a representative International Committee to make arrangements for future International Conferences, and urged all countries interested in horticulture to appoint a delegate so that the Committee could become truly representative. He explained that seventy-one States had agreed to support the International Institute of Agriculture at Rome and if any Bureau of Horticulture became necessary it would seem desirable to consult the Institute before taking further action. F. Szasz, Budapest, declared that a permanent Bureau for International Horticultural Congresses was needed and he gave an account of the work it would do. He suggested it should have the same function for horticulture as the Rome Institute of Agriculture has for agriculture.

On all the points raised Specialist Committees were set up by the Congress to study the view expressed and to report further to the next International Horticultural Congress.

The International Horticultural Committee at their meeting in Vienna accepted the invitation extended by the Royal Horticultural Society of Great Britain that the next International Horticultural Congress should be held in London in 1930.

H.V.T.